Spatial-Intelligent Decision Support System for Sustainable Downstream Palm Oil Based Agroindustry within the Supply Chain Network: A Systematic Literature Review and Future Research

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Abstract — **Oil palm plantations as one of the sexiest commodities; produce a high yield of oil and fat that can be used in various sectors. The prospect of oil palm and its derivative products is good, but there are obstacles and problems faced that are mainly related to sustainability issues in oil palm plantations and its downstream process. Therefore, it is important to study the decision-making process that is needed to develop sustainable palm oil agroindustry. This paper aims at providing a comprehensive literature review for the decision support system for sustainable agroindustry. Totally, 189 scientific publication articles from 2008 to 2019 were reviewed and synthesized. The reviewed articles were categorize based on the keywords of palm oil sustainability, geographic information system (GIS), and decision support system (DSS). The research gap and pointers for future research that are identified is the lack of sustainability aspect inclusion on the decision-making process. We also identified the lack discussion of integrated spatial and intelligent tools through DSS for better, faster, and smarter decision-making process. In the end part of the paper, a pointer for possible future research was developed in terms of the combination through spatial-intelligent system applying business analytics for sustainable agroindustry.**

Keywords — *Decision Support System (DSS), Geographic Information System (GIS), palm oil downstream, sustainability*

1. Introduction

Indonesia oil palm plantations are the largest in the world, with 51.37 % owned by private enterprises, 6.32 % owned by state enterprises, and 42.31% owned by smallholder farmers [1]. Ref. [2] has been stated that oil palm plantations have been widely developed not only by state enterprises, but also by private enterprises and smallholders. Due to the productivity and economic benefits, oil palm plantations grow rapidly [3], especially ones that are developed by smallholder farmers. Also, oil palm is also known has low production costs and can produce more oil from less land [4]. This makes oil palm is 'being sexy', because with not too large investments, high economic returns from oil palm plantations can be obtained with limited labor and minimal maintenance. The oil palm plantations also led to its agroindustry expansion [5], [6] in Indonesia, driven by the global demand growth for oil palm products and its development to people's economy [7] that also will gain the downstream jobs [8]. The wide area evolves of oil plantations is due to its production purpose in many aspects both for food, chemical, and biofuel [9], [10], known to have a beneficial contribution and competitive advantage in its use [11], [12]. This is also related to the prospect of developing palm oil downstream which is expected to be excellent because of the increasing demand and world dependence on palm oil products in the present and future [13], [14]. Ref. [15] present that 87% of the oil and fat's world demand comes from vegetable oils and this need has increased by 14.1% in 2012-2016 and continues to increase every year. Therefore, Ref. [9] stated that the oleo-food, oleo-chemical and biofuel industries have a production capacity of 42.9 million tons/year in 2015-2019 to reach 75 million tons/year from 2025-2035. The development plan of the palm oil downstream industry's production capacity is also

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predicted to increase the demand for palm oil raw materials by 25.30 million tons/year in 2015-2019 to 47.50 million tons/year in 2025-2035. This is support by the development of various technological needs for palm oil downstream starting from oleo-food production, specialty fats production, biomaterial production, active material/component extraction, conversion and purification, thermochemical and bioconversion, and other various technologies.

Ref. [16] stated that in macro terms, the prospect of the Indonesian palm oil industry was quite good, but the obstacles were quite a lot, such as overlapping policies, inadequate infrastructure, the lack growth of downstream industries, the low selling prices, and the absence of government coordinated grand strategy to develop downstream industries. In addition, Ref. [17] also stated that the challenges for the national palm oil industry included the demand for higher quality products, the demand for renewable energy, and the use of palm derivative products as a substitute for oil, the Indonesian palm oil campaigns, and the contribution of the palm oil industry in achieving sustainable development targets. Thus, the development of derivative products is essential to increase the value of palm oil. This is also linking to the development of new markets both domestic and foreign.

Because of that, oil palm plantations and agroindustry is also known face controversy because the rapid development of oil palm contributes to deforestation, loss of biodiversity, forest fires, and many social issues [4], [10], [18]. The forest land use for oil palm plantations also causing threat for palm oil agroindustry production, so it is needed the decision-maker to control the development of both plantations and the agroindustry [19]. These things also will cause impacts to the oil palm agroindustry, due to directly negative influence affects to sustainability aspects including economy, social, environment, and others. The sustainability issues also affect to the selling process of palm oil and its derivative products, the export market rejection due to the destruction of those aspects. The huge issue was delivered to oil palm products from smallholder farmers, it remains problems because of inequitable practices in the agricultural process resulting in lower productivity, sustainability issues, and poor land use [3], [5], [12]. There still exists significant gaps to achieve sustainability outcome [20]. Furthermore, its agroindustry also produce biomass waste during the process and causes environmental problems [21]. To fulfill the downstream policy, the biomass can proceed into bio-products, biofuels, and bioenergy [22].

Many researchers have studied the sustainability of oil palm plantations and the agroindustry, but it still lacks on showing the actual geographical data of its sustainability problem and potential improvement. However, geographical/spatial use of data to determine the sustainability conditions of oil palm is needed for ease of decision making, hence, it can form a policy scenario to improve sustainability aspects [23]. Ref. [24] also presents that geographical data through remote sensing applications based on GIS is useful in support the sustainability monitoring in oil palm plantations and its agroindustry. Ref. [2] also stated that the geographical data i.e. satellite imaginary is useful for decision making. It is famously known as spatial decision support, where the geographical attribute provided to the decision [25]. Due to the previous statement, GIS becomes an important aspect included in the decision-making process [26], [27]. Nevertheless, the GIS research in palm oil studied only in plantations, such as in [12], [24], [27], [28] but minor in its agroindustry i.e. Ref. [21] has use the GIS to define the distribution of empty fruit bunch and select the new area for the power plant.

The decision making of the described condition is a fundamental part to choose the optimum path of these issues with the limitations over the meaning conditions to create policies [29]. Hereinafter, the complexity of decision making due to the knowledge differences resulting in the needs of convenience and interactive media in making decisions. Decision support systems are known to facilitate the stages of decision-making into an interactive computer-based system that imitates real-world conditions, to help make decisions based on data and models from the unstructured problems [30]. To accommodates the decision making complexity condition, the DSS is applied to provide the accurately and adequately insight to decision-makers and helps to formulate decision-making scenario as a prescriptive approach [11], [31]. The use of DSS in the agroindustry field is also needed due to the management opportunities and challenges face by various decision-makers and stakeholders in agroindustry. Ref. [32] told that agriculture and its downstream agroindustry are very complicated issues with complex challenges resulting in the declining of profitability. So, DSS is really important and useful for management guidance. DSS also knew through its ability to interpret as information system based on the use of computer that utilizes decision rules, models, and database comprehensively to solve problems in interactive, adaptable, and flexible ways [32].

From the introduction discussion above, the development of DSS has become a crucial thing to simplify the decision-making process in sustainable downstream palm oil-based agroindustry, including spatial aspect to the decision process in an intelligent framework. So, this paper aims to identify, analyze, synthesize, and compare the models in building the SIDSS for sustainable downstream oil palm agroindustry design to find methods, areas of discussion, approach, and its formulations. The review was constructed in systematic steps, start from identifying and classifying the existing condition and problems of oil palm and its agroindustry in the introduction section. From the introduction above, the review process focused on three main models involved, which are the sustainability of oil palm, GIS for oil palm, and DSS. The article analyzes the important concern of SIDSS comprehensively to map gaps and future possible research. It also can generate an improvement based on reviews' results. The SIDSS is quite important to discuss, due to the needs of stakeholders to decide accessible way facilitation.

2. Method

2.1. The framework of systematic literature review

The literature review was arranged systematically, started from identifying and classifying the agroindustry DSS into three main topics. The topics were sustainability of oil palm, geographic information system for oil palm, and decision support system. First, the authors summarized the articles based on each topic, so articles' classification and description can be concluded. Second, the authors synthesized the articles into cluster or group to see the decision support system in several articles. Third, it needs to compare all of the articles based on years of publication and its development study to find the contrast of previous studies. Finally, the authors identify the research gap and pointers for future research, in the end part. The framework of the systematic literature review is depicted in Figure 1.

2.2. Publication source and analysis

The research method was start with selecting articles that appear through the keywords used, such as 'smallholders of oil palm', 'palm oil downstream products', 'palm oil future prospect product', 'palm oil sustainability', 'sustainable of palm oil', 'palm oil geographic information system', 'agroindustry decision support system', 'intelligent decision support system', 'smart decision support system', 'spatial data mining', 'spatial decision support system', 'spatial-intelligent decision support system', and 'spatial smart decision support system'. The selecting articles found through the keyword used, divided into four main topics describes in Table 1 with the number of articles reviewed. The articles were traced using Google Scholar and Scopus. Totally, 189 scientific publications that published in 2008 till 2019 related to the main topics has been reviewed. The scientific publications overview based on year of publication shown in Figure 2 and were selected from journals, proceedings, books, thesis, statutes, and others.

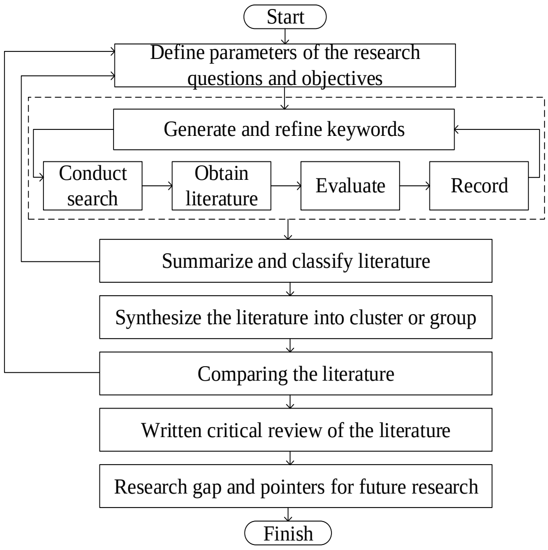

Figure 1. The literature review process (modified from [33])

Table 1. The number of scientific articles reviewed

No	Main Topic	Quantities
1	Oil Palm	40
2	Sustainability	57
3	Geographic Information System	34
4	Decision Support System	55
	Total	**186**

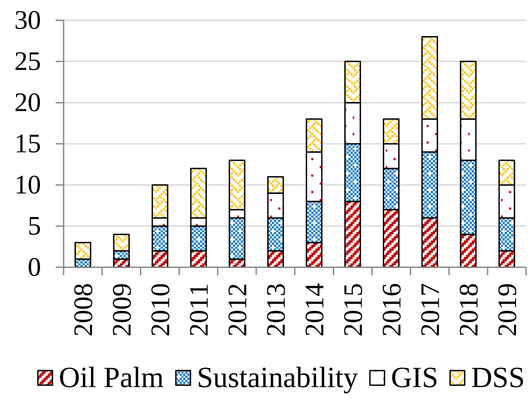

Figure 2. The distribution years of articles

3. Results and Discussion

3.1. Palm oil downstream opportunity

Palm oil is extracted from the ripened mesocarp of oil palm fruits [34], produces crude palm oil (CPO) from the mesocarp and palm kernel oil (PKO) from the inside kernel. The utilization of palm oil reaches about 90% in the food industry, while the remaining 10% is applied in oleo-chemical manufacturing. Palm oil has a unique fatty acid profile that makes it suitable for numerous food applications, it consists of almost 50-50 saturated and unsaturated fatty acids composition. These properties make palm oil increasingly valuable for various uses [35]. The palm oil composition and its chemical fraction derivative as shown in Figure 3 and Figure 4. The main fraction of CPO yields palm oleic as the liquid fraction and palm stearin is the solid fraction [34] known as the most beneficial vegetable oils with high productivity and usable in the various aspects of human life. Oil palm also contains various components like fatty acids, glyceride, carotenoids, tocopherols, beta-carotene, vitamins, and other micronutrients; that demonstrate major nutritional and health advantages [34].

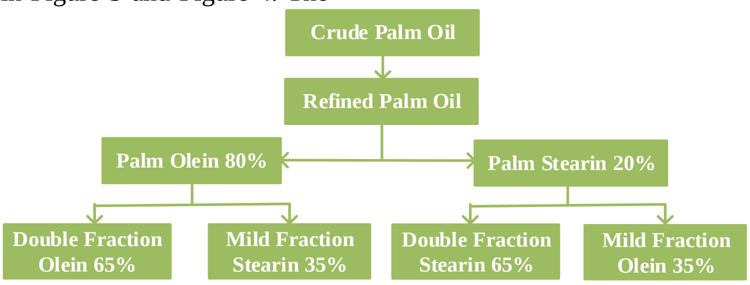

Figure 3. Palm oil composition ([36])

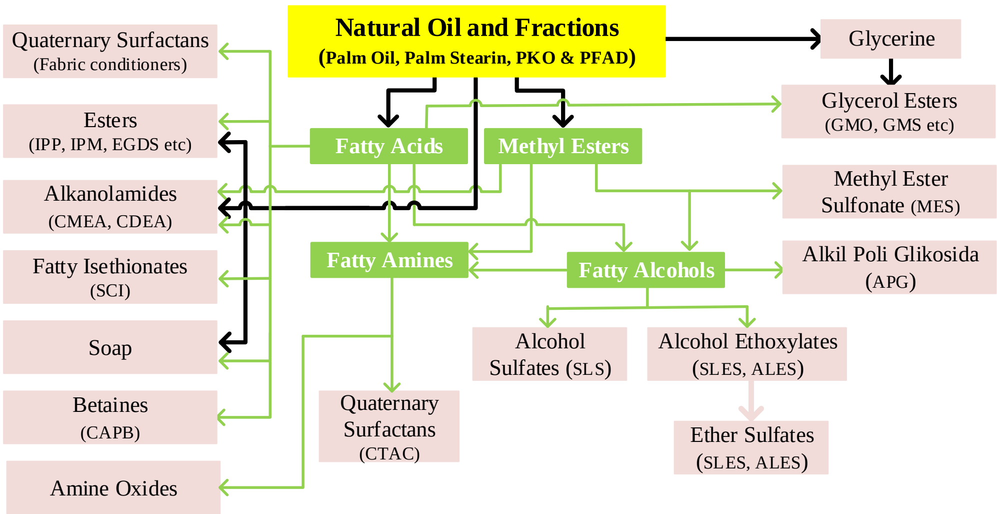

Figure 4. Palm oil chemical fraction derivative ([36])

In the long term, oil palm development and its derivative products are expected to be a future economic development and able to improve the competitiveness [37] behalf on the continuous boom due to global demand for various uses [38]–[40] which increase revenue and decrease waste [4]. Otherwise, Ref. [41] stated that the Indonesian palm oil industry was in a developing condition but only in the upstream part, while the downstream development was still very slow and the composition of exports was still dominated by CPO. The widely use of palm oil in the world to fulfill global demand [42], [43] is found literally in every product from beverages to cosmetics, due to its highest productivity compare to other vegetable oils [44]. This being one of the reasons that palm oil needs to process in producing its derivative products [9], [45]–[47]; so the lack of Indonesia downstream palm oil development needs to finish. Ref. [8] also support the statement of prospects for downstream employment to industrialize the palm oil resulting promising economic growth [48]. The palm oil downstream is thought to be the correct strategy in ensuring sustainable competitiveness [49]. Numerous opportunities within the palm oil sector can add value through product diversification or known as downstream [35]. Palm oil downstream is an effort of structural change carried out by Indonesia in order to transform traditional economic activities as an exporter of CPO into an exporting country of palm oil derivative products in an effort to develop palm oil downstream industries so that it has more added value by processing into semi-finished or finished products [46] and also higher export value [49]. Ref. [9] states that the direction of the development of the palm oil downstream industry includes: a. Oleo-food industry: oleic, stearin, glycerol, Palm Fatty Acid Distillate

(PFAD), cocoa butter substitute, margarine, shortening, other specialty fats; b. Oleo-chemical industry: Vegetable fatty acids, fatty alcohols fatty amines, methyl ester sulfonates (bio-surfactants), bio-lubricants, glycerin chemical-based, essential oils, Isopropyl Palmitate (IPP), Isopropyl Myristic, and Stearic acid; c. Bio-fuel industry: Biodiesel (Fatty Acid Methyl Ester/FAME), Bio jet fuel; d. Feed industry: Rations and animal feed and supplements; e. Wood products industry: woodworking, laminated and finger joint. The scheme of downstream oil palm production flow as shown in Figure 5.

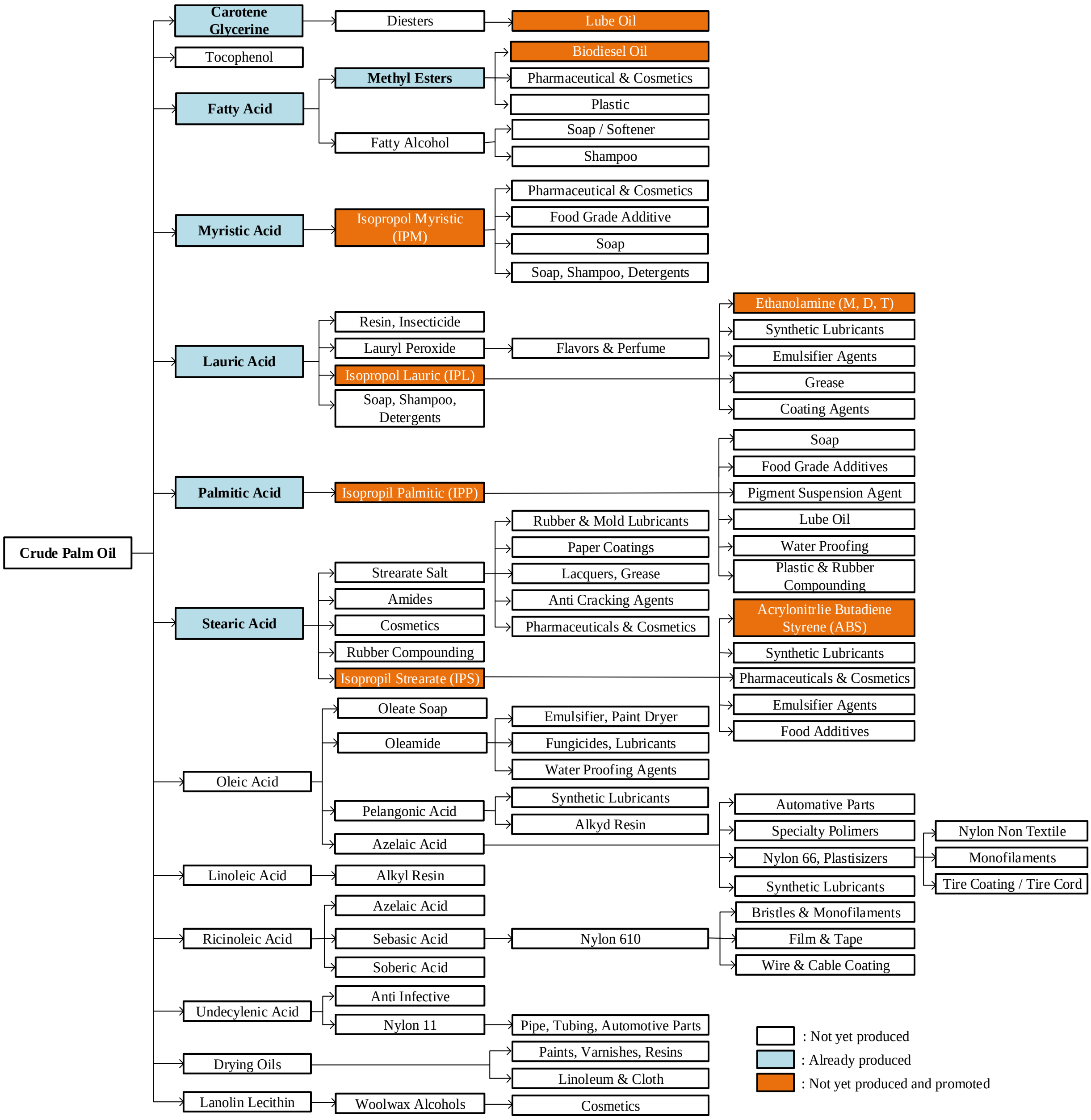

Figure 5. The scheme flow of palm oil downstream [9])

In relation to the process of oil palm replanting program for the downstream palm oil development, the context of downstream must be seen fundamentally not only to process CPO into derivative products that have high added value, but also from the use of oil palm stems and midribs which is cut down in the replanting process. Based on the physical characteristics of the oil palm stem and the 25 years production cycle (with a replanting rate of 4%/year) and the assumption of oil palm area in Indonesia 9.261 million hectares (2011) will produce palm oil waste is around 81.5 million cubic meters/year. Oil palm stem and midrib can be used as bioenergy, its juice can be used as bioethanol, while the fiber can be processed into pellets that can be used as a substitute fuel for coal. Other residues from oil palm oil include trunks, fronds, empty fruit bunches, fiber, and shells [50]. Utilization of oil palm trunks for bioenergy can be as an alternative of downstream palm oil development in the aim of fuel independence which suppresses import substitution and renewable sources of raw materials [21].

Ref. [51] has conducted research related to the manufacture of bioethanol from oil palm waste with enzymatic treatment, so that the flow of bioethanol process becomes one of the potential downstream pathways. The scenario of oil palm biomass used for bioelectricity also has risen in various studies [52], [53]. In addition, Ref. [54] states that the development of the bioethanol industry based on palm oil waste is interesting to develop because of the abundant availability of raw materials. Moreover, biodiesel also one of the downstream important steps due to its benefit in renewable transport fuel [55]. The structure of the palm oil downstream path reconsiders the palm oil along upstream to downstream chain, Ref. [52] model a palm oil supply chain structure in estimating the bio-products path of conversion based on demand and supply-driven; also its technological conversion rate. Further, Ref. [56], [57] also state that the government has promoted the energy mix policy by using biofuels palm oil-based to decrease the environmental impacts. The sustainable use of biofuel is one of a further milestone in downstream through the roadmap for future possible biofuel industry [58] to raise community awareness of biofuel benefits to reduce carbon emissions. Furthermore, the collaboration among all the stakeholders in the chain will build the main strategy to push the palm oil industry toward sustainable production requirements [59], [60].

In other views, a downstream policy of palm oil generated new opportunities for smallholders to participate in the process [61], [62]. Smallholder farmers of oil palm known as one of the most important stakeholders in supporting palm oil downstream policy, due to the 42.31% palm oil crop is owned by smallholder [1], [63] because of its benefit in socio-economic. Smallholder has the potential power to increase downstream process to secure mutual advantage [64] in both upstream and downstream process [65], developing successful strategies for future sustainable downstream in both sectors [66] and knowing the ability of oil palm plantation to downstream development and its potential to improve business opportunity [67]. Otherwise, one of the challenges facing in the downstream process is the low productivity and sustainability of the smallholder plantation [68] causing some social and environmental destruction [63]. The sustainable intensification of smallholder plantations is expected to be knowledgeable to maximize their productivity [69]. As we know, the major problems of oil palm plantation and its agroindustry are related to the environment aspect, i.e. Ref. [70] stated that biomass-based energy is still questionable because of the environmental and social impacts contribution. Then, Ref. [71] also states that Indonesia palm oil industry faces several challenges to implement sustainable practices along the supply chain, including to increase smallholder palm oil productivity. Furthermore, most smallholders are underperformed regarding sustainable production practices and mostly have no certificate [72] and causing indirect impacts in long-term sustainability [73]. The plantations expanding also has led to unsustainable land use [52], climate change [38], and other negative environmental-related impacts due to the less intention in controlling the plantation [74].

The palm oil produced from smallholder plantation also resulting in the lower yield and quality than the other stakeholders. Then, lack of capital or financial access is one of the obstacles happen to smallholder in developing their plantation [75]–[78], moreover the use of unidentified seedling and minimum technical support of plantation resulting this gap of quality and at low efficiency [18]. Meanwhile, plantations' productivity and downstream capability highly depend on supply-driven [79], [80]. Furthermore, the obstacles that happened need government support to improve in nurseries for high-quality seeds and agricultural practices [81], [82]. Moreover, palm oil industry growth and environmental quality improvement can achieve by good agricultural practices implementation [75], [76]. Also, most of obstacles happened through the smallholders has hugely proposed solutions by previous studies like in Ref. [63], [82]. The various previous researchers conclude that the main problems and solutions proposed to palm oil plantation-to-industry is related to its sustainability wider aspects, resulting in un-appropriate quality and products decline by market. It concludes because the favor of short-term economic gain over sustainable development [83]. These sustainability-risen issues also made decision-makers need to rethink due to negative influences on the environmental aspect which indirectly affect the economic aspect. Due to the economic significance of oil palm as an industrial crop, the acquisition of accurate and timely information about its agronomy is critical for the realization of best management strategies [28], [71]. In Ref. [69], the progressive initiate of sustainability would provide the opportunity to increase productivity and market access significantly. Moreover, the fact of the involvement of smallholders in palm oil downstream policy needed the work of government intervention policies. Moreover, the fact of the involvement of smallholders in palm oil downstream policy needed

the work of government intervention policies [84] both ways to enhancing the sustainability of smallholder practices and global market acceptance. It can achieve through sustainability certification owned by smallholders that potentially will support better livelihood [85], [86]. By its sustainable production and its certification, smallholders can optimize yields, get fair prices, give positive social impacts, and release minimal environmental impact [72]. It also concludes that palm oil certification will increase the profitability of smallholders and other related benefits [87] and technical efficiency can improve through socio-economic aspects of smallholder farmers [5]. However, the sustainability researches still needed to support the downstream of palm oil based agroindustry.

3.2. Approach and method for oil palm sustainability

3.2.1 Sustainability definition, current issues, and standard

The sustainability concept has arisen along with the environmental issues and other aspects, involved globally to increase productivity and cost efficiency also processes in upstream to downstream business [88]. With this statement, the discussions of sustainability concept continue to develop and being published in various studies, increasingly. The sustainability concept holds the principle of the natural balance needs and avoids the natural damage that will threaten human life in the present and future [88]. Sustainable development is known as an effort to improve the lives quality so that humans can live in a healthy environment, improve social conditions [89], and opportunities to continues improvement [90]. Based on the three main pillars concept of the sustainability aspect, there are the economic, social, and environmental aspects. In addition, the development of sustainability aspects concept also known as the 3P (Profit, People, and Planet) concept [13]. The view of the sustainability concept does not only consider economic development in environment concept, but also other important aspects in the form of social society. The statement support by Ref. [88] whose states that natural resources should be utilized by paying attention to aspects of equity and social justice for stakeholders. The social sustainability system needs to be emphasized on improving quality rather than quantity growth aspect, it can be achieved through systematic community participation. In addition, Ref. [91] also holds that besides the economic and ecological/environmental dimensions, the concept of sustainable development also needs to pay attention to social aspect to equitable distribution of benefits, participation, community empowerment, and the elimination of poverty. Furthermore, the understanding of the sustainability concept has developed a lot, not only on the three main pillars, but has considered several aspects such as technology, politics, and even institutions [92]–[94].

International interest in sustainable agriculture [39], [95] leading to how the issues of sustainability become the most important aspect to concerned about. The higher consumer expectation and the debate around the sustainability demand is a necessary condition to fulfill [96]. Its sustainability mindset is exceptionally challenging but gives huge implications; not in plantations but also in the industry side [97]. Moreover, the sustainability issues need to take care to meet the standards across the value chain [85], [98] and the sustainability standards being crucial as guidance to sustainable practices in agricultural-related sectors [59], [85], [99]. The palm oil sustainability also facing unresolved debate [100] and rising of sustainability concerns resulting from several standards and certifications as the policy design [98], [101], [102] to secure sustainability issues. Moreover, the certification becomes a prerequisite for tradable products to get market access and product legality [103]. Based on the previous statement in various issues of palm oil sustainability, the implementation of a sustainable system and its assessment is a must and needs to be urgently explored. Meanwhile, the best strategy for sustainability improvement is focusing on operations [104]. According to [105], sustainability assessments ideally should be more focused on determining appropriate indicators on the development of objects studied. However, the sustainability assessment depends on the indicators chosen [42]. Starting from setting the target to determining the best practice decisions is very reliant by the most suitable used indicators determined. The sustainability assessment has to minimize the negative impacts, also maximizing the potential of sustainability benefits [106]. Sustainability assessment indicators that have risen in palm oil are based on the sustainability standards that have been published, the sustainability standards used in oil palm practices include the Roundtable of Sustainable Palm Oil (RSPO) and Indonesian Sustainable Palm Oil (ISPO) which focus on plantations, processing and manufacturing, and palm oil-based industries. The RSPO is a global organization that issues certification for oil palm plantations and agroindustry, the RSPO sets 128 assessment criteria for the sustainability of oil palm [36]. Whereas, ISPO is a policy issued by the Indonesian government to increase the competitiveness of Indonesian palm oil on the world market [99], with 94 criteria for assessing the sustainability of palm oil. The ISPO criteria are specific for smallholders [72], including land certificate obligation, contractual guidelines, and good agricultural practices. The RSPO and ISPO certifications should become the guidance in regards to fulfilling the applicable sustainability action in palm oil-related sectors.

3.2.2 Sustainability method and approach

Previous sustainability assessment in the palm oil is based on determining indicators focused by conditions that resulting a comprehensive assessment. The Analytical Hierarchy Process (AHP) method used in [107] to assess bioenergy sustainability index using economic, social, and environmental aspects. The Analytical Network Process (ANP) method used by [13] with BOCR (Benefit, Cost, Opportunity, Cost and Risk) criteria the developing the palm oil industry and its derivative products based on the social, environmental, technological, political and economic dimensions. A study of the sustainability of the palm oil industry in the concept of industrial clusters by using the Multi-Dimensional Scaling (MDS) method with an assessment of the economic, social, environmental, infrastructure, technology, and institutional dimensions [108]. Further, a study on the palm oil biodiesel products sustainability using the Life Cycle Assessment (LCA) method which focuses on identifying global environmental aspects and impacts related to oil palm cultivation in Indonesia [109], also a review of sustainability aspects for improving the performance of the palm oil supply chain with an assessment of the economic, social, environmental and technological dimensions, the authors used ANP-BOCR method [3]. Furthermore, [53] also carried out sustainability assessments for bioenergy from oil palm using the MDS method by taking into account environmental, economic and social dimensions; the aspects choose through the standards set out in the Global Bioenergy Partnership (GBEP). The various methods used for the assessment of sustainability indexes with such indicators as summarized as in Table 2 and Figure 6 can be considered as a model for the sustainable development of independent smallholders' downstream oil palm development in Indonesia. Based on a study of these previous studies, this study will try to combine all aspects of the study to assess sustainability in the downstream oil palm of independent smallholders as a new future possible research.

Table 2. Previous studies about palm oil sustainability

Authors	Year	Object	Env	Eco	So	Tec	Pol	Ins	Method
[107]	2013	Wood-based bioenergy	√	√	√		√	√	AHP
[13]	2014	Palm oil industry	√	√	√	√	√		ANP-BOCR
[99]	2014	Oil palm plantation	√	√	√				MDS
[107]	2014	Palm oil based biofuels	√	√	√				Peer-reviewed
[108]	2015	Palm oil industrial cluster	√	√	√	√		√	MDS
[99]	2016	Oil palm plantation	√	√	√				MDS
[100]	2016	Palm oil based biodiesel	√	√	√	√	√		Descriptive analysis
[109]	2017	Palm oil based biodiesel	√	√		√			LCA
[63]	2017	Smallholder oil palm plantation	√	√	√		√		In-depth interview
[65]	2017	Palm oil supply chain	√	√	√				Performance analysis
[3]	2018	Palm oil supply chain	√	√	√	√			ANP-BOCR
[53]	2018	Palm oil based bioenergy	√	√	√				MDS
[23]	2018	Palm oil based biofuels	√	√	√	√			Peer-reviewed
[110]	2018	ISPO	√	√	√		√		Descriptive analysis
[20]	2019	Biogas in palm oil mills	√	√	√				Palm oil sustainability assessment

Env = Environment; Eco = Economy; So = Social; Tec = Technology; Pol = Policy; Ins = Institution

The AHP and ANP methods used for sustainability index assessment is a supporting model through the multifactor problems and complex multi-criteria breakdowns into a structured hierarchy or network [111]. This method is used to obtain relative priority interests based on the individual judgment that is influenced by all systematic dependencies in the structure [112]. However, the sustainability index valuation method use AHP or ANP has disadvantages because qualitative assessment of experts has a large impact on the results of the weights obtained [113], [114] and the results obtained are difficult to converge due to differing consistency of expert ratings. Another comprehensive method used for sustainability assessment is the LCA method that measures the impact of environmental sustainability by integrating economic values and integrating the entire supply chain development cycle from the very upstream to the downstream. LCA comprehensively evaluates the environmental impact on the life cycle of a product or service which includes infrastructure, energy supply, raw material extraction, manufacturing (cradle-to-gate), cradle-to-grave distribution [115]. However, in the use of the LCA method, the main factor that is considered in the assessment is the environmental dimension, while the other dimensions become the supporting dimensions for assessing the environmental dimension [116].

Another study on sustainability assessment used the Multidimensional Scaling (MDS) method. Ref. [53] state that MDS method is considered to have advantages because of several things, namely: 1) flexible weighting can be carried out on sustainability aspects, 2) able to visualize sustainability for each aspect or dimension in a simple aggregate dimension horizontally, with a range of sustainability scales ranging from 0% to 100%, interpreted qualitatively as the lowest level of sustainability to the highest level of sustainability. In addition, the parameter that becomes a measurement in determining the sustainability status of a program using this method is concluded in the form of a sustainability index. Ref. [92] also stated that MDS is a statistical analysis to find out the similarities and dissimilarities of variables described in geometric space. The size used to measure the relationship among objects is proximity, which means the closeness of one object to another. Based on this, the MDS method is the most appropriate method that can be used for evaluating the sustainability index.

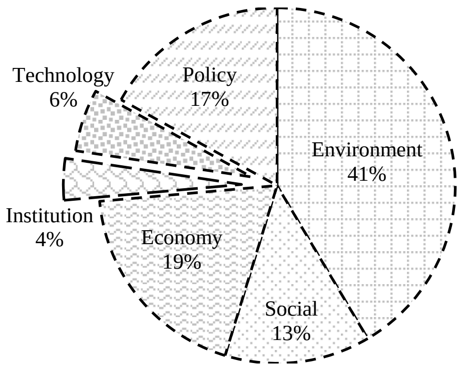

Figure 6. The sustainability aspects studied

Furthermore, sustainability assessment indicators, as stated in Table 2, is based on environmental dimension, economic dimension, social dimension, technological dimension, policy dimension, and institutional dimensions that have been chosen to assess the sustainability of the independent smallholders' palm oil downstream. In this study, the addition of the technological dimension is important to note because it influences the improvement of the quality of sustainability standards for independent smallholders' palm oil downstream, the technological dimension is also considered important concerning performance evaluation and supply chain risk that occurs in independent smallholders in the palm oil supply chain [3]. Ref. [52] claimed that technology plays an important role in the downstream process concerning the supply chain. It is also stated that the technology transfer capability is one of important in agricultural practices to produce higher palm oil productivity [74]–[76]. The policy dimension is considered important because it is very relevant to government policies in supporting the program for the downstream of palm oil which has been proclaimed through oil palm replanting, training in Good Agricultural Practices (GAP), creating beneficial markets conditions, and mandatory for oil palm consumption and taxes [117], [118]. It is also connected to institutional and economic development [119]. Meanwhile, institutional dimensions are important to be considered in independent smallholders' palm oil downstream, due to in the implementation of downstream oil palm there are several challenges in terms of independent smallholder land certification, high capital needs, and institutions that are not active in their function to accommodate oil palm supply chain activities [120], [121]. Moreover, Ref. [45] stated that the institutional role is needed due to the relation of sustainability aspects among many stakeholders. Finally, technological and institutional aspect in sustainability will impact in a higher quality product that increases the smallholders benefit [85] and ensure sustainability of smallholder productivity [75], [76]. Otherwise, technology and institution still lacks in discussion compared to others aspects and it is a novel of future research.

3.3. Geographic information system (GIS) and its usage

The GIS mainly used to collect spatial data and support spatial analysis [122]. The GIS techniques can provide a powerful analytical technique for precision agriculture [2], [123]. This technique is an integrated model between the database management system (DBMS) and the global positioning system (GPS) to produce a spatial representation of data and information, used maps as the basis of decision making [124]. Many agricultural fields have data based on geographical attributes, so that GIS is an important tool for use in agricultural analysis. Based on this, GIS is important to be incorporated into DSS [27], [32]. GIS is considered powerful decision-supporting tools capable of performing spatial engineering analysis in several different environmental modeling application [2]. The benefits of GIS that the system is accessible anytime and anywhere, also the users can know the environment of oil palm plantations that can be used to help in plantations managerial and the implementation of better practical management [123], [125]. Meanwhile, the information of palm oil will narrow to sustainable productivity and a better assessment of its aspects [126]. From the previous statement, spatial planning frameworks will illustrate the nature of sustainability challenge [56] and its monitoring system-generated data that can help to improve sustainability and prioritizing poorly performing and rapid response to problems [127]. Meanwhile, estimating the positive and negative impacts of sustainability require accurate maps [128] and the inclusion of its geographic aspect will provide more confident policy recommendations [129] to compiled into the decision-making tool [65]. It is hoped will help to increase the sustainability performance while also providing important information to decision making [130] and develop better knowledge [131] on conducting sustainable downstream palm oil into the SIDSS.

The GIS or remote sensing technology is widely used, for estimating the age of plants and counting trees [132]–[135]. The remote-sensing technology can use for abandoned oil palm plantations [12] and oil palm growing areas [136]–[138]. In managerial oil palm, high-resolution remote sensing images are very important, especially in decision making. Independent smallholders' oil palm plantations research is done by [12] used satellite imagery with a 30 meters spatial resolution to identify and classify plantations. This research was conducted based on plant development to determine the characteristics of vegetation changes. Planning for good and optimum land use needs to be done to increase productivity, which not only focuses on economic aspects but also environmental conservation aspects [2], [139]. Meanwhile, the smallholders mapping is needed in term of improving the legality of smallholders [47] and also to achieving sustainability goals and more efficient land-use [78]. Therefore, smallholder oil palm plantation being a great challenge due to its limited spatial information in scientific-based [68]. Otherwise, [52] claimed that his study of modeling palm oil supply chain geographically was done for the first time and had not been used in other studies before; it is provided with a proper technique of application and implementation [132], moreover this may ultimately help to gain access to good-quality baseline information [136].

Ref. [2] state that the translation of satellite images into data is useful in decision making and the artificial intelligence used are the convolutional neural network (CNN) and genetic algorithm (GA) methods. This is useful for converting satellite image data so that it can be utilized in decision making, by making a scenario for land use sustainability with maximizing economic factors, minimizing CO_2, and minimizing land degradation. The use of CNN for satellite image processing is known to produced accuracy between 75-91% [27], as a method inspired by the biological nervous system, this method produces simple but interconnected functions [2], while GA is used for multi-objective optimization. The study used CNN and GA methods to produce the optimum solution by taking into account the spatial aspects, namely the height of the land. The CNN method is used to classify plant types in the research area, then the optimization process is carried out with the GA method to produce the most optimum solution for precision agricultural and agroindustry problems.

Ref. [9] conducted development of the classification of oil palm plantations with a rule-based approach to extract attributes from the oil palm plantation area based on the NDVI (normalized difference vegetative index) value. Based on the results of the research, it can be seen that oil palm plantations can be classified as abandoned plantations, abandoned plantations, and others. The level of accuracy of the modeling is known to be 92 ± 1% based on spatial assessment. A visualization development of plant diseases that occur in oil palm plantations for better practical management [37] modeled in stages, including the collection of satellite image data, the construction phase of the three-dimensional model, and the development and implementation of the system's phase. Furthermore, the spatialized production model has been studied by Ref. [140] to modeling sustainable pam oil resulting in the allowance to simulate a sustainable production model and underline the potential use for decision making. Ref. [141] has conducted spatial research to accommodate transportation networks to balancing the supply and demand of palm oil narrowing to the enviro-economic optimization. Moreover, Ref. [142] conducts the simulation scenario models of lowering environmental impacts through a spatial database, resulting the lower impacts but depends on economic dimension planning. Ref. [143] also develop the spatial planning for sustainable oil palm biomass to result cost-effectiveness and mitigate transboundary haze.

3.4. Decision support system

3.4.1 Decision support system definition

The DSS can interpret as an information system based on the use of the computer that utilizes decision rules, models, and databases comprehensively to solve problems in interactive, adaptable, and flexible ways [32], [144]. DSS is known as a technical services response to a work procedure in order to accumulate, analyze, complete, verify, suggest, and show evidence of fact-based evaluation, finding, conclusions, and recommendations [145]. DSS can centralize the data and information, thus concludes that the decision can be taken quickly and precisely [11] and used in expert knowledge modeling [146]. The DSS as a knowledgeable system helps the decision-makers to take decision soon in an emergency [147]. Since the DSS was built in the 1970s, it has been a huge source of help with different management problems in a wide area. The DSS uses is known as a guideline to use information effectively and efficiently [32] that is focused on supporting and improving managerial decision-making [148].

The DSS needs to simplify decision makers to take a credible decision from a set of feasible alternatives limited by specific constraints [11], although it will never completely change the cognitive capacity in making multiple decisions [149]. It also intended to describe the elements of the systems in detail, so it can support the decision making process [150] more efficient because it is faster, cost-effective, and more practical [151]. DSS also facilitating the accelerated learning/acquisition of the knowledge and its improvement as a result of the organization and representation effort [152]. Thus, DSS is applied as an interactive computer program that uses analytic methods for developing models to help decision-makers formulate alternatives, analyze their impacts, and interpret and select appropriate strategies for implementation [32]. With the flexible and interactive characteristics of the DSS, the system helps the decision-maker adopt a problem-oriented approach for solving the problem effectively, efficiently [153], and supportively help users to make better and consistent decisions [148]. But, it also needs to consider the impact of a decision-making process that may have negative consequences [149]. Furthermore, the DSS is highly needed in the agricultural related sectors, which has a high risk with such complex, diverse, uncertain, multiple levels of abstraction, and characteristics of agriculture product [32], [152], [154]. The DSS for agriculture related sectors impact to tackle complex problems and utilizing best available data and knowledge about best practices [155]. The use of DSS in agricultural-related sectors have been widely used; such as in rubber agroindustry [150], [151], oil palm plantations development [37], [156], the supply chain for palm oil based-bioenergy [157], optimization in palm oil industrial waste [158], [159], horticulture supply chain management [160], oil price forecasting [161], coconut new product concept [162], traceability for tuna [163] and much more.

Based on the types, Ref. [32] differentiates DSS into three types, that are a passive DSS, an active DSS, and a cooperative DSS. A passive DSS knew as a system that aids the decision-making process but it can't conclude decision solutions. An active DSS can conclude decision solutions. Furthermore, a cooperative DSS is the most attractive DSS equal to previous DSS, because it permits the decision-makers to modify, complete, and refine the decision solutions continuously till the consolidated solutions are generated. Due to this, the DSS also develops into several models, fulfilling the previous failures' models to meet the needs and requirements of users, also in which environment the DSS being implemented [32] and the needs of the judgmental reasons for the made decisions [164]. The models of developed DSS to accommodate the needs and requirements in scientific articles depicted in Figure 7. From the articles that have been reviewed, there is only 4% of articles that focused on the SIDSS.

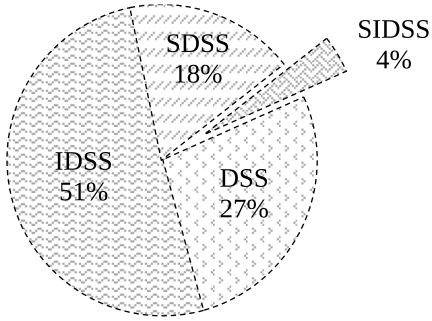

Figure 7. The developed DSS in articles

3.4.2 Decision support system development

Many types of DSS has developed by authors, but we briefly review three types of DSS that arise in the latest era. The DSS as depicted in Figure 7 is IDSS, SDSS, and SIDSS. Firstly, Intelligent Decision Support System (IDSS) as one of the evolution types of DSS, provide users the intelligent assistance capability that significantly improves the decision making quality [148]. IDSS has been used widely for prediction, optimization, and decision making challenges [165]. The IDSS appear due to the previous systems that are lack of efficiency, limited computational ability, inadequate, and impreciseness nature of handling sustainable problems. Despite, the IDSS have used for high computational power of intelligence system to integrate, analyze, and share a large volume of unstructured data in real-time, using the diverse analytical technique to discover sustainable information suitable for better decision making. This includes knowledge management component which stores and manages a new class of emerging artificial intelligence (AI) tools such as machine learning and case-based reasoning and learning, playing the intelligent assistant role to the decision-maker [148], [166]. It also consists of a set of linguistic language or a set of fuzzy predicates to express knowledge [146]. The inclusion of the AI is as an effort to develop computer-based systems that mimic human qualities, intended to improve the ability of decision-makers to better perform their duties and work together [152], [167]. This AI also completely give a new approach to DSS [168] and incorporating more complex representations for data and more intelligent capabilities [169].

Ref. [152] states AI is a study to make computers do things at which, at the moment, people do better; it contributes to knowledge representation, search strategies, and reasoning methods. The AI tools are useful to extracting knowledge from previous data and decisions that give DSS capability to support repetitive, complex real-time decision making. The widely use of IDSS has shown a significant impact in improving consistency, transparency, and objectivity of decision making [144] through specific knowledge and a variety of data mining tools and technologies [170]. The terms of IDSS also known of its adaptability, to change with learning capacity and to provide decision-makers with the capacity of making rational decisions in real-time [171], which defines as the system's ability to change in its environment to ensure continuing survival [152], [171] and many studies focusing on IDSS rather than AI systems. Meanwhile, the IDSS known as the result of DSS and AI that combined, also stated that IDSS is designed and developed using several AI tools [157]. In IDSS, the activities in decision making including data acquisition, data pre-processing, and data transformation [172]. The IDSS design must present the ability of how the problem solved by the decision-maker and then present this ability into a computer-based interface [122], the structure of IDSS design has not changed even the technologies have [173].

In Ref. [153], IDSS used to evaluate and select ships under uncertainty in marine transportation, using a multi-criteria method known as fuzzy multi-criteria analysis. They designed IDSS to help the decision-maker to choose the most suitable ship in a user-friendly manner by allowing the decision-maker to express their requirement linguistically. In Ref. [157], an IDSS used to search the optimum supply path in used palm oil-based bio-energy in due to its supply chain perspectives. The authors recommend integrating the method used with fuzzy logic in the last section. In Ref. [174], a smart DSS developed for rice irrigation management and planning for future climate change forces scenario. The benefit of smart-DSS is decision-maker can make fast-decision due to comprehensive rapid simulation and more practical.

Secondly, a DSS that support semi-structured spatial problems in decision making is needed because of its effectivity support in decision making of spatial aspects that cannot be modeled or measured [175], therefore the spatial decision support system (SDSS) framework was created to identify and compare to spatial decision problems. Based on the previous statement, the GIS is considered a generator for SDSS due to its power and efficient function to store, retrieve, analyze, manipulate, and display large volumes of spatial digital data and to create maps [151], [175]–[177], also accommodate multiple attributes in making better decisions. The using of SDSS plays a huge role due to its more possible decision modeling of external data, including more practice visualization to show the problems and solutions scenario to decision-makers [26], [178]. The use of spatial data has more advantages to provide decisions to support more available data to captures [26], it also supports by Ref. [179] whose stated that SDSS looks at the problem situations to cover the entire problem posed, yet GIS only looks at the data. The SDSS is also known as an extension of GIS software to support decisions [180].

Furthermore, most of the agricultural data have geographic attributes, so GIS is an important tool for agricultural analysis and including GIS into DSS [32] and real decision support tools [181]. This also stated by Ref. [166] that in the era of global village, the geographical and temporal boundaries are shrinking rapidly as a key element in decision making management. Ref. [177] also stated that due to the wide range of spatial information, the SDSS is qualified to be used. It will allow and encourage stakeholders to access and participate in the decision-making process with the awareness of the existence of spatial data and scientific models. The SDSS also has proliferated into individualizes location-based services, dynamic systems taking advantage of frequent data updates and public sector decision support applications relying on public participation and abundant data streams collected from a variety of location-aware sensors [26].

Lastly, the combination to integrate spatial data techniques with the intelligence tools provide the ability of the DSS to apply both statistical and mining techniques in the spatial form [182], it makes the decision makers have a wide view [29] of the current situation from different perspectives due to the different data nature. The integration of all technologies in one unified system can provide an intelligent interface for data storage, database access, and data display using GIS; also provide expert assistance in the decision making process [183] as a spatial intelligent DSS (SDISS) framework. The main contribution of SIDSS is the possibility to integrate the other sources with spatial data to take better decision recommendations [182]. Ref. [122] integrate spatial information and computational intelligence in a system to simplify the decision making in selecting site and location alternatives for industrial. The system consists of classification alternatives for the industrial site using GIS and site selection using the neuro-fuzzy system. They claimed that it needs only three days of the process to classify industrial sites alternatives using the GIS and IDSS. Then, Ref. [151] had developed SIDSS to measure and select the best strategies of green productivity in rubber agroindustry, consists of spatial conditions, productivity level and index, and its best strategies. The summary of the developed DSS topics reviewed is as described in Table 3.

Table 3. The DSS topic's reviewed

Topic	Journal Title	Authors	Year	Object	Description
Intelligent Decision Support System	AFITA 2010 International Conference	[154]	2010	Agriculture supply chain management	The framework of IDSS proposed for supply chain management to negotiate prices and to balance risks.
	Jurnal Teknologi Industri Pertanian	[160]	2010	Horticulture supply chain management	An IDSS was developed to optimize horticulture supply chain management, consists of 8 models including planning process till its transportation.
	Applied Soft Computing	[184]	2011	Medical therapy	The IDSS proposed by authors conclude that the system has the impacts to improve the clinical quality of decision making and affecting the services' relationship between patient and doctor.
	Jurnal Teknologi Industri Pertanian	[157]	2011	Palm oil based bio-energy	The IDSS used to search the optimum supply path in palm oil-based bio-energy supply chain.
	Expert System with Application	[153]	2012	Marine transportation	The IDSS presents in the paper to evaluate and selects specific available ships
	Applied Soft Computing	[185]	2014	Rehabilitation monitoring	The research proposed the integration between knowledge-based system and intelligent methods to develop a monitoring framework for injury cases.
	International Journal of Computer Applications	[167]	2015	Medical	The paper is a recent survey for classification problems using multi-agent IDSS.
	International Journal of Computer Applications	[162]	2015	Coconut shell wood	The IDSS was developed to selecting the new derived products from coconut shell wood vinegar.
	International Journal of Information Science and Management	[161]	2015	Oil price forecasting	The research built the IDSS for predicting the price of crude oils using a hybrid intelligent algorithm to ensure decision-makers in economic planning and taking effective recommendations.
	IEEE Journal Systems	[122]	2018	Industrial site	The IDSS presents for industrial site classification based on quality criteria in the geographic information system to propose location and site alternatives.
Spatial Decision Support System	Pertanika Journal of Science and Technology	[156]	2009	Oil palm plantation management	The SDSS was used to predict for olds oil palm plantation replanting; using integrated remote sensing, GIS, and AHP technologies. The tool has been made operational to support the decision making for replanting.
	International Journal of Geosciences	[186]	2011	Watershed management	The SDSS developed in a web-based application, showing spatial factors that affect the watershed planning and management.
	International Journal of Geography and Regional Planning	[181]	2014	Market policy	The research recommends SDSS using the integration of GIS and multi-criteria analysis methods addressed to decision making effectiveness.
	International Journal of Critical Infrastructure Protection	[175]	2019	Road transportations	The SDSS can easily be used to determining transportation network performance in disaster conditions.
	Journal of Cleaner Production	[179]	2019	Onshore wind energy development	The SDSS was developed to develop the feasibility of collective intelligence analysis of energy transition in spatial locations.

Topic	Journal Title	Authors	Year	Object	Description
Spatial-Intelligent Decision Support System	International Journal of Engineering and Science	[32]	2012	Agriculture	A theoretical framework was developed by authors to specifically making the decision in agriculture more accurate and more accessible, moreover to create the solution model for agriculture problems.
	International Journal of Productivity and Performance Management	[151]	2017	Rubber agroindustry	The SIDSS used to measure productivity and select the best strategies of rubber agroindustry's green productivity based on spatial conditions and productivity levels.

3.4.3 Decision support system method and approach

The method and approach used in DSS based on three types of DSS have been reviewed, shown in Table 4. From Table 4 below, it was known that most of DSS use various methods in spatial scope and AI tools. Nevertheless, the lack of literature shown the integrated approach of spatial and AI combination. This is potential as a universal integration to advance the DSS that will develop by authors. The new insights of DSS also state by [170] in the form of business intelligence and spatial analytics innovations to improve the data analysis and generate more objective and data-based decisions. From the previous statement, so it needed to comprehend the data analytics and its strategic steps to make valuable and smart decision support in the systematic collaboration of AI and spatial tools. Otherwise, from Table 4, it is also known that the sustainability aspects used in DSS have not been various in aspects. Those things being a novelty of the future possible research for smallholder palm oil downstream development agenda in making sustainable policy and related-decision making in a DSS base.

Table 4. The DSS approach and method used

Authors	Year	GIS	ES	SUS				FM	ACO	MAS	MCDM	CBR	FIS	ANFIS	GA	ANN
				En	So	Ec	Po									
[32]	2012	√	√	√	√	√	√	√								
[157]	2011							√	√							
[122]	2018	√											√	√		
[175]	2019	√									√					
[151]	2017	√		√		√		√								
[153]	2012							√								
[154]	2010							√	√				√			
[160]	2010										√				√	
[161]	2015							√								√
[162]	2015										√					√
[167]	2015									√						
[186]	2011	√		√												
[179]	2019	√		√												
[181]	2014	√									√					
[184]	2011							√			√		√			
[185]	2014							√				√				

GIS = Geographic Information System; ES = Expert System; SUS = Sustainability; En = Environment; So = Social; Ec = Economy; Po = Policy/Politics; FM= Fuzzy Multi-Criteria Method; ACO = Ant Colony Optimization; MAS = Multi Agent Systems; CBR= Case Based Reasoning; FIS = Fuzzy Inference Systems; ANFIS = Adaptive Neuro-Fuzzy Inference Systems; GA = Genetic Algorithm; ANN= Artificial Neural Network

4. Research Gap and Pointers for Future Research

The sustainable downstream palm oil are expected to be a future economic development and increasing bargaining positions of Indonesia palm oil in the global market. The sustainable palm oil downstream to achieve market requirements and gave policy recommendations involved in modeling palm oil downstream path along the supply chain is needed; due to negative impacts arises in palm oil business process; moreover to the smallholder palm oil product that widely uncertified. The most sustainability aspects discuss are related to environment, economy, and social; while the other aspects still lack in discuss. Based on those things, the authors try to define other aspects related to sustainability, concluding three other aspects possible and important to take care of as shown in Figure 6. The sustainability aspects that obtain a lack of consideration is technology, institution, and policy. Meanwhile, those aspects will increase higher quality and productivity [74], relevant in supporting government programs [121], and accommodate the stakeholders [45]. Based on the review, it also concludes that sustainability and the related decision-making problems that arise in palm oil downstream are essentially conflicting [88]. The creation and enforcement of sustainability standards is critical to the success of managing sustainable downstream palm oil, so that it must be considered and the various stakeholders should be involved [6]. The harmonization understanding of sustainability among stakeholders needs to be seen as policy systems that rule the business process [110] and the integrated instruments to face specific problems to the sustainable downstream of palm oil [187], resulting future sustainability studies will hopefully mapping the sustainability performance [115]. Using the sustainability approach will enable the consideration of alternative solutions that may be more prospective [179].

Furthermore, expanding knowledge from spatial aspect; into palm oil plantation and its downstream opportunity; will enrich information [68] and necessary to decision-makers. The further possible research offers as a novel of the research is the integrated sustainability assessment in geographic information systems. The inclusion of its geographic aspect will provide more confident policy recommendations [129] to compiled into a decision-making tool [65]. Indonesia, in fact, still not have any official database of oil palm plantations and its palm oil-based agroindustry in geographical locations [52] being the challenge of future research. Meanwhile, a reliable palm oil database is crucial to make relevant policy recommendations; so hopefully, the sustainability path can also be improved. Thus, this area of study is very potential to be explored to make a reliable decision making in simple yet on-point solutions. In the relation of the sustainability assessment integrated into spatial tool needs to be considered as one integrated DSS as [182] had suggested applying the integrated approach in a user interface helped with supportive tools.

The integrated DSS of the previous statement has been risen by previous authors. Ref. [179] offering an integrated holistic approach of spatial analysis and environmental analysis to provide valuable strategic information to enable environmental development more sustainable, participative, open and transparent. Ref. [188] also state that most environmental systems visualization adds the spatial relationships between the environmental aspects to make the decisions more accurate and reliable. There are many open research lines for solving problems through DSS, with the function of AI, GIS, and environmental science. Ref. [176] stated that the integration of GIS needs broader analysis to allow researchers to enhance visualization with advance analytics performance. There are chances of expanding the research, especially in developing an intelligent group of SDSS to allow the decision-makers to contribute in the system by using intelligent software agents [175]. AI can also be used as a basic model or way to communicate among other models such as GIS [188]; it can embed each other and suggest applying granular computer techniques to design the SIDSS [171]. Otherwise, the main challenges of this collaborated research are integrating spatial data with other data resources, dealing with heterogeneous data, and visualizing the results in an interactive method [182]. The sustainability aspects are also mapped as the limitation of [186] SDSS was that the model developed without social and economic aspects. Ref. [179] recommend developing a comprehensive system in economic, social, and geopolitical models. Furthermore, the challenge for the broad applicability of SIDSS is to design a system that can effectively interact with humans, can gain human trust in the system, and can solve impactful applied problems [189]. The gap study of the SIDSS and the integrated sustainable spatial model as shown in Figure 8.

To conclude previous systematic literature reviews and research gaps identified, the term sustainable in the palm oil downstream-related process has a very significant impact to escalate the effectiveness and efficiency of palm oil downstream development. To be more accessible, the spatial scope of this sustainable palm oil downstream is considered to be as an appropriate concept to be integrated into DSS since visualization imagery of spatial context will be easier to be understood by decision-makers and various stakeholders. The future possible steps are by developing smallholders is through maximizing benefits in downstream palm oil-based agroindustry. This objective can be achieved by the cooperation among stakeholders and also government to strengthen the smallholder position in the downstream process [87], also the sustainability of palm oil smallholder to meet the process and market requirements. The derivative products also need to initiate in order to advantage the palm oil produced by smallholders can reduce the negative impacts of market acceptance. Furthermore, the market chains for smallholders also need to be constructed by the government to increase market opportunities and reliable prices. The appropriate decision and policymaking are greatly needed in this term of sustainable palm oil downstream 'taken of advantaged'. Implementation of decision making of its sustainable downstream scenario to produce palm oil downstream path's policies or strategies is organized in the form of SIDSS. The policies or strategies model in this system is collaborate the spatial and knowledge base data in each of the sustainable aspects measures. The policy scenario in this SDSS has a huge function to make an appropriate decision to take by decision-makers based on valuable information and a certain environment. To conclude everything that has been stated before, the design of the SIDSS for sustainable downstream palm oil-based agroindustry is proposed as depicted in Figure 9.

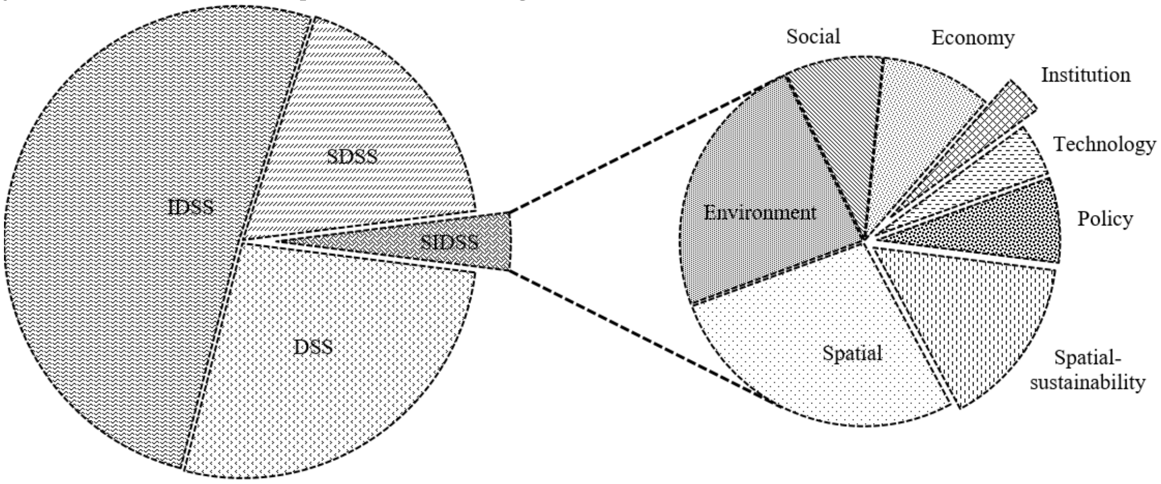

Figure 8. The SIDDS in literature and gaps

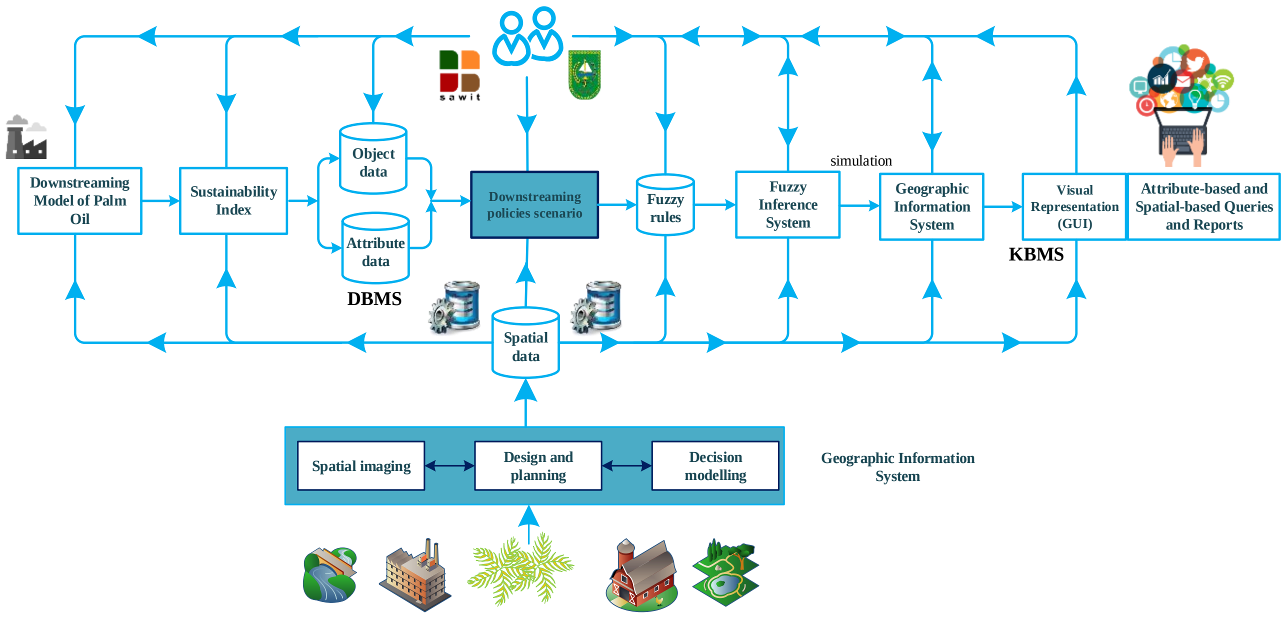

Figure 9. The framework of the SIDSS for sustainable downstream palm oil-based agroindustry (modified from [122])

5. Conclusions and Recommendations

This article, therefore, draws three main conclusions. First, the widely use of palm oil derivative products in various products resulting in the need for development to the downstream of palm oil-based agroindustry. Its shows by the policies and many publications that stated about the derivative products of palm oil. Second, the sustainability that is the most concern of the global market needs to be addressed behalf in welcoming the sustainable downstream palm oil to achieving the settle bargaining position of Indonesia palm oil. The sustainability aspects that need to be addressed are based on the three sustainability main pillars (environment, social, and economy) and three other additional aspects (technology, policy, and institution) as a novel of further research. Based on the review results, we suggested to exploring further research in developing the integration of sustainability assessment in the spatial system to make the decision-making better in visualization and more understandable by stakeholders. Third, the decision-making process of sustainable downstream palm oil needs to simply in the form of innovation DSS. We suggested the SIDSS framework that slightly used, as a new approach to accommodate and construct the possible improvement to problems faced.

From the previous conclusion, the future possible research is to build an innovative SIDSS to develop the strategic policies for sustainable downstream palm oil-based agroindustry. It is a novel concept to develop new integrated approach of AI and spatial tools in terms of collaborative decision-making. The framework of the SIDSS has been proposed in this review, in order to map the research guideline. The research opportunity for palm oil downstream combined various aspects of sustainability to create a sustainable downstream strategy policy in the organized system. The SIDSS will lead to strategic foresight of future policy planning. Finally, it will conclude the easiest and fastest way to make appropriate decisions. It is expected that the SIDSS would decrease the time needed to make decisions and optimize palm oil downstream-related evaluation through the spatial-intelligent system and knowledge-based information using more visualization.

References

[1] Direktorat Jenderal Perkebunan, *Statistik Perkebunan Indonesia 2016-2018: Kelapa Sawit*. Jakarta: Kementerian Pertanian Republik Indonesia, 2017.

[2] Firdaus, Y. Arkeman, A. Buono, and I. Hermadi, "Satellite image processing for precision agriculture and agroindustry using convolutional neural network and genetic algorithm," in *IOP Conference Series: Earth and Environmental Science*, 2017, vol. 5, pp. 1–7.

[3] Marimin and Safriyana, "Evaluation of palm oil supply chain's performance, added value, and performance improvement: A case study at X Co.," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 196, no. 1, 2018.

[4] D. Sheil *et al.*, *The impacts and opportunities of oil palm in Southeast Asia What do we know and what do we need to know?* Bogor, Indonesia: Centre of International Forestry Research, 2009.

[5] W. Alwarritzi, T. Nanseki, and Y. Chomei, "Analysis of the Factors Influencing the Technical Efficiency among Oil Palm Smallholder Farmers in Indonesia," *Procedia Environ. Sci.*, vol. 28, pp. 630–638, 2015.

[6] C. Petrenko, J. Paltseva, and S. Searle, "Ecological impacts of palm oil expansion in Indonesia," 2016.

[7] H. Hamdani and K. Mustofa, "A Review: Clearing Oil Palm Plantation with Multi-Stakeholder Model," *Int. J. Comput. Appl.*, vol. 115, no. 2, pp. 1–10, 2015.

[8] T. M. Li, "Social Impacts of Oil Palm in Indonesia: A Gendered Perspective from West Kalimantan," Bogor, 2015.

[9] Kementerian Perindustrian Indonesia, "Rencana Induk Pembangunan Industri Nasional 2015 - 2035," 2015.

[10] L. Rist, L. Feintrenie, and P. Levang, "The livelihood impacts of oil palm: Smallholders in Indonesia," *Biodivers. Conserv.*, vol. 19, no. 4, pp. 1009–1024, 2010.

[11] Safriyana, T. Djatna, Marimin, E. Anggraeni, and I. Sailah, "An analysis and design of downstreaming decision system on palm oil agroindustry based on multilabel classification," *2018 Int. Conf. Adv. Comput. Sci. Inf. Syst. ICACSIS 2018*, pp. 247–252, 2019.

[12] N. M. Yusoff, F. M. Muharam, S. Khairunniza-bejo, N. M. Yusoff, F. M. Muharam, and S. Khairunniza-bejo, "Towards the use of remote-sensing data for monitoring of abandoned oil palm lands in Malaysia : a semi-automatic approach," *Int. J. Remote Sens.*, vol. 38, no. 2, pp. 432–449, 2017.

[13] B. A. Wisena, A. Daryanto, B. Arifin, and R. Oktaviani, "Sustainable Development Strategy and the Competitiveness of Indonesian Palm Oil Industry," *Int. J. Manag. Stud. Res.*, vol. 2, no. 10, pp. 102–115, 2014.

[14] B. A. Wisena, A. Daryanto, B. Arifin, and R. Oktaviani, "Sustainable Development Strategy for Improving the Competitiveness of Oil Palm Industry," *Int. Res. J. Bus. Stud.*, vol. 7, no. 1, pp. 13–37, 2017.

[15] S. M. Sinaga, "Masa Depan Industri Hilir Indonesia," Solo, 2017.

[16] Suharjito and Marimin, "The Institutional Model of Palm Downstream Industry Development," *J. Teknobisnis*, vol. 7, no. 1, pp. 20–40, 2012.

[17] E. Wibowo, "Pendanaan Penelitian dan Pengembangan Sawit Berkelanjutan," Yogyakarta, 2017.

[18] T. Soliman, F. K. S. Lim, J. S. H. Lee, and L. R. Carrasco, "Closing oil palm yield gaps among Indonesian smallholders through

industry schemes, pruning, weeding and improved seeds,” *R. Soc. Open Sci.*, vol. 3, no. 8, 2016.
[19] I. K. Gunarta, A. M. Fauzi, and B. S. Kusmuljono, “Pengembangan Industri Crude Palm Oil Berkelanjutan Dengan Menggunakan Model Geo-Spatial Multicriteria Decision Analysis,” vol. 13, no. 1, pp. 16–26, 2013.
[20] C. I. Lim and W. K. Biswas, “Sustainability implications of the incorporation of a biogas trapping system into a conventional crude palm oil supply chain,” *Sustainability*, vol. 11, no. 3, 2019.
[21] Y. L. Chiew, T. Iwata, and S. Shimada, “System analysis for effective use of palm oil waste as energy resources,” *Biomass and Bioenergy*, vol. 35, no. 7, pp. 2925–2935, 2011.
[22] T. M. I. Mahlia, N. Ismail, N. Hossain, A. S. Silitonga, and A. H. Shamsuddin, “Palm oil and its wastes as bioenergy sources: a comprehensive review,” *Environ. Sci. Pollut. Res.*, 2019.
[23] A. P. Saravanan, T. Mathimani, G. Deviram, K. Rajendran, and A. Pugazhendhi, “Biofuel policy in India: A review of policy barriers in sustainable marketing of biofuel,” *J. Clean. Prod.*, vol. 193, pp. 734–747, 2018.
[24] K. L. Chong, K. D. Kanniah, C. Pohl, and K. P. Tan, “A review of remote sensing applications for oil palm studies,” *Geo-Spatial Inf. Sci.*, vol. 20, no. 2, pp. 184–200, 2017.
[25] J. Coutinho-Rodrigues, A. Simao, and C. H. Antunes, “A GIS-based multicriteria spatial decision support system for planning urban infrastructures,” *Decis. Support Syst.*, vol. 51, no. 3, pp. 720–726, 2011.
[26] P. B. Keenan and P. Jankowski, “Spatial Decision Support Systems: Three decades on,” *Decis. Support Syst.*, vol. 116, no. October, pp. 64–76, 2019.
[27] M. Längkvist, A. Kiselev, M. Alirezaie, and A. Loutfi, “Classification and segmentation of satellite orthoimagery using convolutional neural networks,” *Remote Sens.*, vol. 8, no. 4, 2016.
[28] S. K. Balasundram, H. Memarian, and R. Khosla, “Estimating oil palm yields using vegetation indices derived from QuickBird,” *Life Sci. J.*, vol. 10, no. 4, pp. 851–860, 2013.
[29] B. Charith, “Creating Policy using Decision Support pattern for Software Project Management,” *Int. J. Supply Chain Manag.*, vol. 7, no. 33, pp. 180–182, 2018.
[30] Marimin, *Sistem Penunjang Keputusan*. Bogor: IPB Press, 2017.
[31] D. Bag, *Business Analytics*. New York: Routledge, 2017.
[32] A. Agrahari and S. Tripathi, “A Theoretical Framework for Development of Decision Support System for Agriculture,” *Int. J. Eng. Sci.*, vol. 1, no. 6, pp. 50–55, 2012.
[33] M. Saunders, P. Lewis, and A. Thornhill, *Research Methods for Business Students fifth edition*. London: Pearson Education, 2009.
[34] O. I. Mba, M. J. Dumont, and M. Ngadi, “Palm oil: Processing, characterization and utilization in the food industry - A review,” *Food Biosci.*, vol. 10, pp. 26–41, 2015.
[35] O. Obire and R. Putheti, “The Oil Palm tree: A Renewable Energy in Poverty Eradication in Developing Countries,” *Drug Invent. Today*, vol. 2, no. 1, pp. 34–41, 2010.
[36] Roundtable on Sustainable Palm Oil, “The RSPO Certified Sustainable Palm Oil Supply Chain : How to take part,” 2018.
[37] A. I. Suroso and A. Ramadhan, “Web-based Decision Support System for Agribusiness Development in Oil Palm Plantations at Siak Local Government Using Policy Analysis Matrix,” *Int. J. Comput. Sci. Issues*, vol. 9, no. 2, pp. 92–98, 2012.
[38] L. Lane, “Economic growth, climate change, confusion and rent seeking: The case of palm oil,” *J. Oil Palm Environ.*, vol. 3, no. 1, pp. 1–8, 2012.
[39] J. Khatarina, “Palm Oil in Indonesia and Natural Resources Management : Why the Lack of a Legal Framework ? Palm Oil Problems : Filtering the Truth,” vol. 19, no. 1, pp. 1–17, 2018.
[40] M. Craw, “Palm Oil Smallholders and Land-Use Change in Indonesia and Malaysia,” 2019.
[41] N. Rifai, Y. Syaukat, H. Siregar, and E. G. Sa’id, “The Development and Prospect of Indonesian Palm Oil Industry and Its Derivative Products,” *IOSR J. Econ. Financ.*, vol. 4, no. 5, pp. 27–39, 2014.
[42] M. P. Van Dijk, “Sustainability, Fair Play and Free Trade in The Modern World, Partnerships for The Development of Sustainability in Malaysia’s Palm Oil Sector,” *J. Oil Palm Environ.*, vol. 3, pp. 75–82, 2012.
[43] P. Oosterveer, “Promoting sustainable palm oil: Viewed from a global networks and flows perspective,” *J. Clean. Prod.*, vol. 107, pp. 146–153, 2015.
[44] Malaysian-German Chamber of Commerce and Industry, *Palm Oil: Awareness and Sustainability, A Global Perspective*. Kuala Lumpur: EU-Malaysia Chmaber of Commerce and Industry (EUMCII), 2017.
[45] J. Hidayati, S. Sukardi, A. Suryani, A. M. Fauzi, and S. Sugiharto, “Palm Oil

Plantation Revitalization Model for The Agroindustry Development," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 8, no. 2, p. 588, 2018.
[46] G. S. Berlian, "Politik Hilirisasi Kelapa Sawit Indonesia," *J. Ilm. Transform. Glob.*, vol. 2, no. 2, pp. 80–100, 2014.
[47] Institut Penelitian Inovasi Bumi, "A Profile of Oil Palm Smallholders and Their Challenges of Farming Independently," p. 76, 2016.
[48] World Growth, "The Economic Benefit of Palm Oil to Indonesia," *World Growth Palm Oil Green Dev. Campaign.*, pp. 1–27, 2011.
[49] R. Y. H. Silitonga, J. Siswanto, T. Simatupang, and S. N. Bahagia, "Modeling policy mix to improve the competitiveness of indonesian palm oil industry," *J. Ind. Eng. Manag.*, vol. 9, no. 1, pp. 231–253, 2016.
[50] S. B. Hansen, R. Padfield, K. Syayuti, S. Evers, Z. Zakariah, and S. Mastura, "Trends in global palm oil sustainability research," *J. Clean. Prod.*, vol. 100, pp. 140–149, 2015.
[51] I. Winarni, S. Komarayati, and T. B. Bardant, "Enzymatic Bioethanol Production of Oil Palm Trunk Waste (Elaeis guineensis) Using Surfactant," *J. Penelit. Has. Hutan*, vol. 34, no. 2, pp. 127–135, 2016.
[52] F. Harahap, S. Leduc, S. Mesfun, D. Khatiwada, F. Kraxner, and S. Silveira, "Opportunities to Optimize the Palm Oil Supply Chain in Sumatra, Indonesia," *Energies*, vol. 12, no. 3, p. 420, 2019.
[53] P. Papilo, Marimin, E. Hambali, and I. S. Sitanggang, "Sustainability index assessment of palm oil-based bioenergy in Indonesia," *J. Clean. Prod.*, vol. 196, pp. 808–820, 2018.
[54] Majalah Sawit Indonesia, "Lestari Pasifik Bhd dan INKUD Bangun Pabrik Bioetanol," pp. 1–13, 30-Aug-2014.
[55] S. A. Archer, R. J. Murphy, and R. Steinberger-Wilckens, "Methodological analysis of palm oil biodiesel life cycle studies," *Renew. Sustain. Energy Rev.*, vol. 94, pp. 694–704, 2018.
[56] Z. R. Anderson, K. Kusters, K. Obidzinski, and J. Mccarthy, "Growing the Economy : Oil Palm and Green Growth in East Kalimantan, Indonesia," in *Land Grabbing, Conflict and Agrarian-Environmental Transformations: Perspectives from East and Southeast Asia*, 2015, no. 20.
[57] K. Obidzinski, R. Andriani, H. Komarudin, and A. Andrianto, "Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia," *Ecol. Soc.*, vol. 17, no. 1, 2012.
[58] N. A. Sasongko, C. Thorns, I. Sankoff, S. T. Chew, and S. Bista, "Transitioning to sustainable use of biofuel in Australia," *Renew. Energy Environ. Sustain.*, vol. 2, p. 25, 2017.
[59] S. Nupueng, P. Oosterveer, and A. P. J. Mol, "Implementing a palm oil-based biodiesel policy: The case of Thailand," *Energy Sci. Eng.*, vol. 6, no. 6, pp. 643–657, 2018.
[60] Y. Su, P. Zhang, and Y. Su, "An overview of biofuels policies and industrialization in the major biofuel producing countries," *Renew. Sustain. Energy Rev.*, vol. 50, pp. 991–1003, 2015.
[61] I. Jelsma, G. C. Schoneveld, A. Zoomers, and A. C. M. van Westen, "Unpacking Indonesia's independent oil palm smallholders: An actor-disaggregated approach to identifying environmental and social performance challenges," *Land use policy*, vol. 69, no. September, pp. 281–297, 2017.
[62] A. Suratin, M. Karuniasa, and S. W. Utomo, "Is Sustainable Oil Palm Production Possible for Smallholders?," *J. Environ. Sci. Sustain. Dev.*, vol. 1, no. 1, pp. 25–39, 2018.
[63] N. Nurliza and E. Dolorosa, "Effect Relationships on Sustainable Development of Palm Oil Production for Independent Smallholder Farmers toward Sustainable Certification System," *J. Sustain. Dev.*, vol. 10, no. 1, p. 24, 2017.
[64] W. Verheye, "Growth and Production of Oil Palm," *Land Use, Land Cover and Soil Sciences*. Encyclopedia of Life Support Systems (EOLSS), UNESCO-EOLSS Publishers, Oxford, UK, p. 10, 2010.
[65] R. A. Hadiguna and B. Tjahjono, "A framework for managing sustainable palm oil supply chain operations: a case of Indonesia," *Prod. Plan. Control*, vol. 28, no. 13, pp. 1093–1106, 2017.
[66] J. S. H. Lee, S. Abood, J. Ghazoul, B. Barus, K. Obidzinski, and L. P. Koh, "Environmental impacts of large-scale oil palm enterprises exceed that of smallholdings in Indonesia," *Conserv. Lett.*, vol. 7, no. 1, pp. 25–33, 2014.
[67] A. Sjahza and B. Asmit, "Regional economic empowerment through oil palm economic institutional development," *Manag. Environ. Qual. An Int. J.*, 2019.
[68] B. Okarda, I. Carolita, T. Kartika, and H. Komarudin, "Mapping of smallholder oil palm plantation and development of a growth model," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 169, no. 1, 2018.
[69] C. Nagiah and R. Azmi, "A Review of Smallholder Oil Palm Production: Challenges and Opportunities for

Enhancing Sustainability - A Malaysian Perspective," *J. Oil Palm &The Environ.*, vol. 3, pp. 114–120, 2012.
[70] D. Harnesk, "Biomass-based energy on the move – The geographical expansion of the European Union's liquid biofuel regulation," *Geoforum*, vol. 98, pp. 25–35, 2019.
[71] J. S. H. Lee, J. Ghazoul, K. Obidzinski, and L. P. Koh, "Oil palm smallholder yields and incomes constrained by harvesting practices and type of smallholder management in Indonesia," *Agron. Sustain. Dev.*, vol. 34, no. 2, pp. 501–513, 2014.
[72] International Finance Corporation, "Diagnostic Study on Indonesian Oil Palm Smallholders: Developing A Better Understanding of Their Performance and Potential," 2013.
[73] S. Budidarsono, A. Susanti, and A. Zoomers, *Oil Palm Plantations in Indonesia: The Implications for Migration, Settlement/Resettlement, and Local Economic Development*, vol. 31, no. 4. IntechOpen, 2017.
[74] A. H. Awang, K. Hashim, Z. Ramli, and I. Ibrahim, "Agriculture Technology Transfer and Productivity of Independent Oil Palm Smallholders," *Int. J. Manag. Appl. Sci.*, no. 3, pp. 2394–7926, 2017.
[75] M. Euler, S. Schwarze, H. Siregar, and M. Qaim, "Oil Palm Expansion among Smallholder Farmers in Sumatra, Indonesia," 8, 2015.
[76] M. Euler, S. Schwarze, H. Siregar, and M. Qaim, "Oil Palm Expansion among Smallholder Farmers in Sumatra, Indonesia," *J. Agric. Econ.*, vol. 67, no. 3, pp. 658–676, 2016.
[77] E. Bronkhorst *et al.*, "Current practices and innovations in smallholder palm oil finance in Indonesia and Malaysia: Long-term financing solutions to promote sustainable supply chains," 2017.
[78] S. Glenday and G. Paoli, "Overview of Indonesian Oil Palm Smallholder Farmers: A Typology of Organizational Models, Needs, and Investment Opportunities," Bogor, 2015.
[79] S. Z. Y. Foong, C. K. M. Goh, C. V. Supramaniam, and D. K. S. Ng, "Input–output Optimisation Model for Sustainable Oil Palm Plantation Development," *Sustain. Prod. Consum.*, vol. 17, pp. 31–46, 2019.
[80] F. Salman, M. Najib, and S. Djohar, "Cost and Benefit Analysis of RSPO Certification (Case Study in PT BCA Oil Palm Plantation in Papua)," *Indones. J. Bus. Entrep.*, vol. 3, no. 3, pp. 219–228, 2017.
[81] D. Chalil, M. Basyuni, R. Barus, and L. A. Putri, "Smallholders' willingness to pay for dura marking oil palm seeds," *E3S Web Conf.*, vol. 52, p. 00011, 2018.
[82] D. Ruysschaert, A. Darsoyo, R. Zen, G. Gea, and I. Singleton, "Developing Palm-Oil Production on Degraded Land: Technical, Economic, Biodiversity, Climate, Legal, anD Policy Implications," 2011.
[83] H. Ivancic and L. P. Koh, "Evolution of Sustainable Palm Oil Policy in Southeast Asia," *Cogent Environ. Manag. Conserv.*, vol. 2, no. 1, pp. 1–10, 2016.
[84] L. Potter, "Managing Oil Palm Landscapes: A Seven-Country Survey of The Modern Palm Oil Industry in Southest Asia, Latin America, and west Africa," Bogor, 2015.
[85] N. K. Hidayat, P. Glasbergen, and A. Offermans, "Sustainability certification and palm oil smallholders' livelihood: A Comparison between Scheme Smallholders and Independent Smallholders in Indonesia," *Int. Food Agribus. Manag. Rev.*, vol. 18, no. 3, pp. 25–48, 2015.
[86] D. M. Onuigbo, B. M. Sinaga, and Harianto, "Oil Palm Policy, Land Use Change and Community Livelihoods (OLCL) in Indonesia: A Sustainability Framework," *Int. J. Environ. Sci. Dev.*, vol. 8, no. 8, pp. 601–605, 2017.
[87] N. K. Hidayat, A. Offermans, and P. Glasbergen, "On the profitability of sustainability certification: An analysis among Indonesian palm oil smallholders," *J. Econ. Sustain. Dev.*, vol. 7, no. 18, pp. 45–61, 2016.
[88] H. Chiou and G.-H. Tzeng, "Fuzzy Multiple-Criteria Decision-Making Approach for Industrial Green Engineering," vol. 30, no. 6, pp. 816–830, 2002.
[89] O. Ortiz, F. Castells, and G. Sonnemann, "Sustainability in the construction industry: A review of recent developments based on LCA," *Constr. Build. Mater.*, vol. 23, no. 1, pp. 28–39, 2009.
[90] S. C. Batubara, M. S. Maarif, Marimin, and H. E. Irianto, "Achieving sustainability in capture fishing industry based on the regional characteristics," *Int. J. Supply Chain Manag.*, vol. 5, no. 3, pp. 40–60, 2016.
[91] C. Asdak, *Kajian Lingkungan Hidup Strategis: Jalan Menuju Pembangunan Berkelanjutan*. Yogyakarta: Gadjah Mada University Press, 2012.
[92] Kholil, T. A. Dharoko, and A. Widayati, "Pendekatan multi dimensional scaling untuk evaluasi keberlanjutan waduk Cirata - Propinsi Jawa Barat," *J. Mns. dan*

Lingkung., vol. 22, no. 1, pp. 22–31, 2015.

[93] T. Kurka and D. Blackwood, “Participatory selection of sustainability criteria and indicators for bioenergy developments,” *Renew. Sustain. Energy Rev.*, vol. 24, pp. 92–102, 2013.

[94] J. K. Musango and A. C. Brent, “A conceptual framework for energy technology sustainability assessment,” *Energy Sustain. Dev.*, vol. 15, no. 1, pp. 84–91, 2011.

[95] L. X. Ni, F. Ali, and Z. H. Zainudin, “Factors Influencing the Implementation of Malaysia Sustainable Palm Oil (MSPO) Among Oil Palm Smallholders in Malaysia,” *Int. J. Acad. Res. Bus. Soc. Sci.*, vol. 6, no. 12, pp. 272–284, 2017.

[96] E. Novelli, “Sustainability as a Success Factor for Palm Oil Producers Supplying the European Vegetable Oil Markets,” *Oil Palm Ind. Econ. J.*, vol. 16, no. 1, pp. 8–17, 2016.

[97] M. A. A. Farid, M. A. Hassan, M. R. Othman, Y. Shirai, and H. Ariffin, *Sustainability of Oil Palm Biomass-Based Products*. Elsevier Inc., 2019.

[98] F. M. Mohd Noor, A. Gassner, A. Terheggen, and P. Dobie, “Beyond sustainability criteria and principles in palm oil production: Addressing consumer concerns through insetting,” *Ecol. Soc.*, vol. 22, no. 2, 2017.

[99] R. Anwar, S. R. Sitorus, A. M. Fauzi, N. Widiatmaka, and N. Machfud, “Achievement of Indonesian Sustainable Palm Oil Standards of Palm Oil Plantation Management in East Borneo Indonesia,” *J. Penelit. Tanam. Ind.*, vol. 22, no. 1, p. 11, 2016.

[100] S. Bautista, P. Narvaez, M. Camargo, O. Chery, and L. Morel, “Biodiesel-TBL+: A new hierarchical sustainability assessment framework of PC&I for biodiesel production - Part i,” *Ecol. Indic.*, vol. 60, pp. 84–107, 2016.

[101] C. Brandi, T. Cabani, C. Hosang, S. Schirmbeck, L. Westermann, and H. Wiese, *Sustainability Certification in the Indonesian Palm Oil Sector*. 2013.

[102] C. Brandi, T. Cabani, C. Hosang, S. Schirmbeck, L. Westermann, and H. Wiese, “Sustainability Standards for Palm Oil: Challenges for Smallholder Certification Under the RSPO,” *J. Environ. Dev.*, vol. 24, no. 3, pp. 292–314, 2015.

[103] S. Hutabarat, “ISPO Certification and Indonesian Oil Palm Competitiveness in Global Market : Smallholder Challenges toward ISPO Certification,” *Agro Ekon.*, vol. 28, no. 2, p. 170, 2018.

[104] A. Hidayatno, Y. M. Zagloel, and W. W. Purwanto, “System Dynamics Sustainability Model of Palm-Oil Based Biodiesel Production Chain in Indonesia,” *IJET Int. J. Eng. Technol.*, vol. 11, no. 3, pp. 1–6, 2011.

[105] V. H. Dale *et al.*, “Assessing bioenergy sustainability using measurable and meaningful indicators,” Tennessee, 2013.

[106] K. Obidzinski, R. Andriani, H. Komarudin, and A. Andrianto, “Environmental and Social Impacts of Oil Palm Plantations and their Implications for Biofuel Production in Indonesia,” *Ecol. Soc. 17(1)*, vol. 17, no. 1, 2012.

[107] T. Myllyviita *et al.*, “Sustainability assessment of wood-based bioenergy - A methodological framework and a case-study,” *Biomass and Bioenergy*, vol. 59, pp. 293–299, 2013.

[108] I. Dharmayanti, H. Hardjomidjojo, A. M. Fauzi, and D. Mulyadi, “Sustainability Analysis of Sei Mangkei Palm Oil Based Industrial Cluster,” *J. Econ. Sustain. Dev.*, vol. 6, no. 4, pp. 176–183, 2015.

[109] S. Hasibuan and H. Thaheer, “Life Cycle Impact Assessment Produksi Biodiesel Sawit Untuk Mendukung Keberlanjutan Hilirisasi Industri Sawit Indonesia,” *Semin. Nas. Inov. Dan Apl. Teknol. Di Ind. 2017 ITN Malang*, pp. 1–7, 2017.

[110] D. K. Habibie, “Political Economy of Indonesia Sustainable Palm Oil (ISPO) Certification System in Riau Province,” *Adv. Soc. Sci. Educ. Humanit. Res.*, vol. 191, pp. 197–209, 2018.

[111] T. L. Saaty, “The Analytic Hierarchy and Analytic Network Measurement Processes: The Applications to Decisions under Risk,” *Eur. J. Pure Appl. Math.*, vol. 1, no. 1, pp. 122–196, 2008.

[112] Y. Lee, W. Wu, and G. Tzeng, “An effective decision-making method using a combined QFD and ANP approach,” *WSEAS Trans. Bus. Econ.*, vol. 12, no. 5, pp. 541–551, 2008.

[113] Ravil and Kant, “A Fuzzy AHP-TOPSIS Framework for Ranking the Solutions od Knowledge Mangament Adopiton in Supply Chain to Overcome Its Barriers,” *Expert Syst. Appl.*, vol. 41, pp. 679–693, 2014.

[114] W. Septiani, Y. Herdiyeni, and L. Haditjaroko, “Method and Approach Mapping for Agri-food Supply Chain Risk Management: A literature review,” *Int. J. Supply Chain Manag.*, vol. 5, no. 2, pp. 51–64, 2016.

[115] A. Avadí and P. Fréon, “Life Cycle Assessment of Fisheries : A Review for Fisheries Scientists and Managers,” *Fish. Res.*, vol. 143, pp. 21–38, 2013.

[116] V. Subramaniam, C. Yuen May, H. Muhammad, Z. Hashim, Y. A. Tan, and P. Chiew Wei, "Life Cycle Assessment of The Production of Crude Palm Oil (Part 3)," *J. Oil Palm Res.*, vol. 22, no. December, pp. 895–903, 2010.
[117] Direktorat Jenderal Industri Agro Kementerian Perindustrian, "Pengembangan Industri Prioritas Agro," Jakarta, 2015.
[118] Badan Pengelola Dana Perkebunan Kelapa Sawit, "Program PSR Peremajaan Sawit Rakyat (Meningkatkan Produktivitas Tanpa Perluasan Areal)," Jakarta, 2018.
[119] H. S. H. H. Alabass, S. N. Harjan, M. Teng, and S. S. H. S. Shah, "The Impact of Corporate Political Connections on Corporate Financial Decisions: Evidence from an Emerging Market," *J. Manag. Inf. Decis. Sci.*, vol. 22, no. 2, pp. 13–24, 2019.
[120] Pusat Penelitian Kelapa Sawit, "Teknis Peremajaan Tanaman Kelapa Sawit," Medan, 2017.
[121] L. C. Wei, "Concept of Oil Palm Replanting Program Indonesia Palm Oil - Land to Production," in *The World Plantation Conference, Grand Sahid Hotel*, 2017.
[122] A. Rikalovic, I. Cosic, R. D. Labati, and V. Piuri, "Intelligent decision support system for industrial site classification: A GIS-based hierarchical neuro-fuzzy approach," *IEEE Syst. J.*, vol. 12, no. 3, pp. 2970–2981, 2018.
[123] R. C. Mat, A. N. Zulkifli, N. Nordin, and S. A. M. Yusof, "A Review on Technique in Managing oil Palm Plantation towards a Digitilized Online 3D Application," *Proc. 4th Int. Conf. Educ. Inf. Manag.*, no. December, pp. 368–372, 2013.
[124] M. Kennedy, *Introducing Geographic Information System with ArcGIS: Third Edition*. New Jersey: John Wiley&Sons, Inc, 2013.
[125] Y. Cheng *et al.*, "Towards global oil palm plantation mapping using remote-sensing data," *Int. J. Remote Sens.*, vol. 1161, pp. 1–16, 2018.
[126] N. Kamiran and M. L. R. Sarker, "Exploring the potential of high resolution remote sensing data for mapping vegetation and the age groups of oil palm plantation," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 18, no. 1, 2014.
[127] S. Walker, A. McMurray, F. Rinaldy, K. Brown, and D. Karsiwulan, "Compilation of Best Management Practices to Reduce Total Emissions from Palm Oil Production," 2018.
[128] L. Li, J. Dong, S. N. Tenku, and X. Xiao, "Mapping oil palm plantations in cameroon using PALSAR 50-m orthorectified mosaic images," *Remote Sens.*, vol. 7, no. 2, pp. 1206–1224, 2015.
[129] S. Sloan and N. Stork, "Geography and Indonesian oil-palm expansion," *Proc. Natl. Acad. Sci.*, vol. 107, no. 45, pp. E171–E171, 2010.
[130] J.-Y. Koay, T.-Y. Yan, K.-S. Lim, and H. T. Ewe, "A Microwave Scattering Model for the Remote Sensing of Oil Palm Plantations," *PIERS Online*, vol. 5, no. 3, pp. 273–276, 2009.
[131] W. A. Teniwut, M. Marimin, and T. Djatna, "GIS-Based multi-criteria decision making model for site selection of seaweed farming information centre: A lesson from small islands, Indonesia," *Decis. Sci. Lett.*, vol. 8, pp. 137–150, 2019.
[132] S. Daliman, S. A. R. Abu-Bakar, and I. Busu, "Oil Palm Tree Enumeration Based on Template Matching Oil Palm Tree Enumeration Based on Template Matching," 2016.
[133] A. C. Fitrianto, A. Darmawan, K. Tokimatsu, and M. Sufwandika, "Estimating the age of oil palm trees using remote sensing technique," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 148, no. 1, 2018.
[134] P. Srestasathiern and P. Rakwatin, "Oil palm tree detection with high resolution multi-spectral satellite imagery," *Remote Sens.*, vol. 6, no. 10, pp. 9749–9774, 2014.
[135] S. Vadivelu, A. Ahmad, and Y. H. Choo, "Remote Sensing Techniques for Oil Palm Age Classification Using Landsat-5 Tm Satellite," *Sci.Int.(Lahore)*, vol. 26, no. 4, pp. 1547–1551, 2014.
[136] I. K. Nooni, A. A. Duker, I. Van Duren, L. Addae-Wireko, and E. M. Osei Jnr, "Support vector machine to map oil palm in a heterogeneous environment," *Int. J. Remote Sens.*, vol. 35, no. 13, pp. 4778–4794, 2014.
[137] H. A. Setyowati, S. H. B. S. Murti, and E. S. Sukentyas, "Effectiveness of Vegetation Index Transformation for Land Use Identifying and Mapping in the Area of Oil palm Plantation based on SPOT-6 Imagery (Case Study: PT.Tunggal Perkasa Plantations, Air Molek, Indragiri Hulu)," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 47, no. 1, 2016.
[138] H. M. Rizeei, H. Z. M. Shafri, M. A. Mohamoud, B. Pradhan, and B. Kalantar, "Oil palm counting and age estimation from WorldView-3 imagery and LiDAR data using an integrated OBIA height model and regression analysis," *J. Sensors*, vol. 2018, pp. 1–13, 2018.
[139] Y. Cheng, L. Yu, A. P. Cracknell, and P.

Gong, “Oil palm mapping using Landsat and PALSAR: a case study in Malaysia,” *Int. J. Remote Sens.*, vol. 37, no. 22, pp. 5431–5442, 2016.

[140] L. Feintrenie, L. Gazull, R. Goulaouic, and L. M. Iii, “Spatialized Production Models for Sustainable Palm Oil in Central Africa: Choices and Potentials,” in *2016 World Bank Conference on Land and Poverty*, 2016.

[141] I. K. Gunarta, Eriyatno, A. M. Fauzi, and B. S. Kusmuljono, “Model Analisis Geo-Spasial Penentuan Jalur Transportasi Industri Crude Palm Oil Menggunakan Algoritma Djikstra,” *INASEA*, vol. 13, no. 1, pp. 1–11, 2012.

[142] J. Garcia-Ulloa, S. Sloan, P. Pacheco, J. Ghazoul, and L. P. Koh, “Lowering environmental costs of oil-palm expansion in Colombia,” *Conserv. Lett.*, vol. 5, no. 5, pp. 366–375, 2012.

[143] S. T. Tan, H. Hashim, A. H. Abdul Rashid, J. S. Lim, W. S. Ho, and A. B. Jaafar, “Economic and spatial planning for sustainable oil palm biomass resources to mitigate transboundary haze issue,” *Energy*, vol. 146, pp. 169–178, 2018.

[144] M. Asrol, Marimin, Machfud, and M. Yani, “Method and approach mapping of fair and balanced risk and value-added distribution in supply chains: A review and future agenda,” *Int. J. Supply Chain Manag.*, vol. 7, no. 5, pp. 74–95, 2018.

[145] C. S. Wasson, *System Engineering Analysis, Design, and Development: Concepts, Principles, and Practices*. New Jersey: John Wiley&Sons, Inc, 2016.

[146] D. S. Comas, J. I. Pastore, A. Bouchet, V. L. Ballarin, and G. J. Meschino, *Soft Computing for Business Intelligence*, vol. 587. Springer, 2014.

[147] S. Jain, *Exploring Intelligent Decision Support Systems: Current State and New Trends*, vol. 764. Springer International Publishing, 2018.

[148] A. Tariq and K. Rafi, “Intelligent Decision Support Systems-A Framework,” *Inf. Knowl. Manag.*, vol. 2, no. 6, pp. 12–20, 2012.

[149] A. Dong and J. Jupp, “Intelligent decision support and modeling,” *Artif. Intell. Eng. Des. Anal. Manuf.*, vol. 26, no. 4, pp. 371–373, 2012.

[150] Marimin, W. Adhi, and M. A. Darmawan, “Decision support system for natural rubber supply chain management performance measurement: A sustainable balanced scorecard approach,” *Int. J. Supply Chain Manag.*, vol. 6, no. 2, pp. 60–74, 2017.

[151] Y. K. Teniwut, M. Marimin, and N. S. Indrasti, *Spatial intelligent decision support system for increasing productivity on natural rubber agroindustry by green productivity approach*, vol. 66, no. 6. 2017.

[152] R. Yost, T. Attanandana, C. Colfer, and S. Itoga, *Decision Support Systems in Agriculture: Some Successes and a Bright Future, Efficient Decision Support Systems - Practice and Challenges From Current to Future*. Croatia: IntechOpen, 2011.

[153] S. Wibowo and H. Deng, “Intelligent decision support for effectively evaluating and selecting ships under uncertainty in marine transportation,” *Expert Syst. Appl.*, vol. 39, no. 8, pp. 6911–6920, 2012.

[154] Marimin, T. Djatna, Suharjito, D. Nugeraha, and E. Bahar, “A Framework of Intelligent Decision Support Systems for Agro-Industrial and Agribusiness Supply Chain Management,” in *AFITA 2010 International Conference, The Quality Information for Competitive Agricultural based Production System and Commerce*, 2010, pp. 236–241.

[155] E. O. Ogunti, F. K. Akingbade, A. Segun, and O. Oladimeji, “Decision Support System using Mobile Applications in the Provision of Day to Day Information about Farm Status to Improve Crop Yield,” *Period. Eng. Nat. Sci.*, vol. 6, no. 2, pp. 89–99, 2018.

[156] L. K. Fook, R. Ponusamy, S. Mansor, and J. Ismail, “A spatial decision support tool for oil palm plantation management,” *Pertanika J. Sci. Technol.*, vol. 17, no. 1, pp. 21–32, 2009.

[157] D. N. Utama, T. Djatna, E. Hambali, Marimin, and D. Kusdiana, “Intelligent decision support systems for searching the optimum palm oil based bio-energy supply chain by using ant colony optimization method,” *J. Teknol. Ind. Pertan.*, vol. 21, no. 1, pp. 50–62, 2011.

[158] D. C. Fibrian, S. Martini, and Marimin, “Decision Support System for Optimization of Waste Utilization of Palm Oilmill Solid Waste,” *J. Teknol. Ind. Pertan.*, vol. 20, no. 2, pp. 130–142, 2010.

[159] A. Ishak and A. Y. Bin Ali, “Decision Support Model for Selection Technologies in Processing of Palm Oil Industrial Liquid Waste,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 277, no. 1, 2017.

[160] Y. Arkeman and R. A. Dharma, “Sistem Penunjang Keputusan Cerdas untuk Mengelola Rantai Pasokan pada Agroindustri Hortikultura,” *J. Teknol. Ind. Pertan.*, vol. 19, no. 3, pp. 152–163, 2010.

[161] H. Chiroma, A. A. Zavareh, M. S. Baba, A. I. Abubakar, A. Y. u. Gital, and F. U. Zambuk, “Intelligent decision support

systems for oil price forecasting," *Int. J. Inf. Sci. Manag.*, vol. 13, no. SpecialIssue, pp. 47–59, 2015.
[162] E. M. Dewi, Y. Arkeman, E. Noor, and N. A. Achsani, "Designing Intelliget Decision Support System for Coonut Shell Wood Vinegar New Product Concept," *J. Teknol. Ind. Pertan.*, vol. 25, no. 2, pp. 94–106, 2015.
[163] B. A. Kresna, K. B. Seminar, and Marimin, "Developing a traceability system for tuna supply chains," *Int. J. Supply Chain Manag.*, vol. 6, no. 3, pp. 52–62, 2017.
[164] K. Yamada, K. Yoshida, M. Kojima, N. Kataoka, and T. Mizuno, *Knowledge-Based and Intelligent Information and Engineering Systems*. Berlin, 2011.
[165] A. K. Sangaiah, A. Ajith, P. Siarry, and M. Sheng, *Intelligent Decision Support Systems for Sustainable Computing: Paradigms and Applications*. Cham: Springer International Publishing, 2017.
[166] T. Perraju, "Artificial Intelligence and Decision Support Systems," *Int. J. Adv. Res. IT Eng.*, vol. 2, no. 4, pp. 17–26, 2013.
[167] H. Salem, G. Attiya, and N. El-Fishawy, "A Survey of Multi-Agent based Intelligent Decision Support System for Medical Classification Problems," *Int. J. Comput. Appl.*, vol. 123, no. 10, pp. 20–25, 2015.
[168] D. G. Pascual, *Artificial Intelligence Tools: Decision Support Systems in Condition Monitoring and Diagnosis*. London, 2015.
[169] M. Mora, Gl. Phillips-Wren, F. C. Perez, L. Garrido, and O. Gelman, *Engineering and Management of IT-based Service Systems: An Intelligent Decision-Making Support Systems Approach*. Berlin: Springer International Publishing, 2014.
[170] A. Felsberger, B. Oberegger, and G. Reiner, "A Review of Decision support Systems for Manufacturing Systems," in *CEUR Workshop Proceedings*, 2016, vol. 1793.
[171] N. Slam, W. Slamu, and P. Wang, "A Prototype Intelligent Decision-Support System with a Unified Planning and Learning Capabilities," *Int. J. Artif. Intell. Tools*, vol. 26, no. 06, p. 1750025, 2017.
[172] R. H. Mule and B. R. Bhamare, "A Review on Intelligent Decision Support System for Operation Theater," *Int. J. Innov. Res. Adv. Eng.*, vol. 1, no. 3, pp. 11–14, 2014.
[173] J. Rasku, P. Kuusipalo, and H. Joutsijoki, "Decision Support Systems Review," 2014.
[174] M. K. Rowshon, N. S. Dlamini, M. A. Mojid, M. N. M. Adib, M. S. M. Amin, and S. H. Lai, "Modeling climate-smart decision support system (CSDSS) for analyzing water demand of a large-scale rice irrigation scheme," *Agric. Water Manag.*, vol. 216, pp. 138–152, 2019.
[175] S. M. Ghavami, "Multi-criteria spatial decision support system for identifying strategic roads in disaster situations," *Int. J. Crit. Infrastruct. Prot.*, vol. 24, pp. 23–36, 2019.
[176] R. K. Sharma, "Review of Spatial Decision Support Systems in Resource Management," *Rev. Bus. Technol. Res.*, vol. 6, no. 1, pp. 167–174, 2012.
[177] Y. Zhang, R. Sugumaran, M. McBroom, J. DeGroote, R. L. Kauten, and P. K. Barten, "Web-Based Spatial Decision Support System andWatershed Management with a Case Study," *Int. J. Geosci.*, vol. 02, no. 03, pp. 195–203, 2011.
[178] R. Sugumaran and J. DeGroote, *Spatial Decision Support Systems: Principle and Practices*. CRC Press Taylor&Francis Group, 2011.
[179] J. J. Diez-Rodríguez, T. B. Fischer, and S. Di Zio, "Introducing a group spatial decision support system for use in strategic environmental assessment of onshore wind farm development in Mexico," *J. Clean. Prod.*, vol. 220, pp. 1239–1254, 2019.
[180] J. Albrecht, "Open Source Foundations for Spatial Decision Support Systems," *Cart. Geogr. Inf. Sci.*, no. 2, pp. 227–239, 2018.
[181] S. Das and M. R. Choudhury, "An integrated GIS and Spatial Decision Support System for Market Policy, Analysis, Research, and Development," *Int. J. Geogr. Reg. Plan.*, vol. 1, no. 1, pp. 2–10, 2014.
[182] A. M. Idrees, M. H. Ibrahim, and A. I. El Seddawy, "Applying spatial intelligence for decision support systems," *Futur. Comput. Informatics J.*, vol. 3, no. 2, pp. 384–390, 2018.
[183] A. F. Lukasheh, R. L. Droste, and M. A. Warith, "Review of Expert System (ES), Geographic Information System (GIS), Decision Support System (DSS), and their applications in landfill design and management," *Waste Manag. Res.*, vol. 19, no. 2, pp. 177–185, 2002.
[184] T. Padma and P. Balasubramanie, "Domain experts' knowledge-based intelligent decision support system in occupational shoulder and neck pain therapy," *Appl. Soft Comput. J.*, vol. 11, no. 2, pp. 1762–1769, 2011.
[185] S. M. N. A. Senanayake, O. A. Malik, P. M. Iskandar, and D. Zaheer, "A knowledge-based intelligent framework for anterior cruciate ligament rehabilitation monitoring," *Appl. Soft Comput. J.*, vol. 20, pp. 127–141, 2014.
[186] Y. Zhang, R. Sugumaran, M. McBroom, J. Degroote, R. L. Kauten, and P. K. Barten,

"Web-Based Spatial Decision Support System and Watershed Management with a Case Study," *Int. J. Geosci.*, vol. 2, pp. 195–203, 2011.

[187] J. McCarthy and Z. Zen, "Regulating the oil palm boom: Assessing the effectiveness of environmental governance approaches to agro-industrial pollution in Indonesia," *Law Policy*, vol. 32, no. 1, pp. 153–179, 2010.

[188] M. Sànchez-Marrè *et al.*, "Intelligent Environmental Decision Support Systems," in *Environmental Modelling & Software and Decision Support*, 2008, pp. 119–144.

[189] G. Phillips-Wren, "Intelligent Decision Support Systems," in *Intelligent Systems Reference Library*, vol. 81, 2015, pp. 31–85.